COAL AGE

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DEVOTED TO THE OPERATING, TECHNICAL AND BUSINESS PROBLEMS OF THE COAL-MINING INDUSTRY

SYDNEY A. HALE, *Editor*

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A Quarter Century of Progress

MEASURED only in years, a quarter of a century is no great span of time; measured by accomplishments, however, such an interval may assume unusual significance or seem an arid waste of opportunities. The technical progress packed into the history of the coal-mining industry since 1911 makes the period just closing truly outstanding. At times, perhaps, with a slowness irritating to the enthusiast, at others with sharply quickened pace—but always moving—engineering skill has marched forward to new achievements against an economic background often shot through with clashing trends and violent change.

NO PHASE of the operating cycle has been left untouched in this advance. Because it is the latest phase to enter large-scale development, mechanization of underground loading now holds the center of the stage. But improvements in many other phases of operation have been no less notable even if the receding years have robbed these older achievements of some of their impact. Look where you will—transportation, mining methods, preparation, maintenance, electrification, ventilation—and the record is one of contribution to better and safer production and to the elimination of much of the hard toil once so intimately associated with the extraction of mineral wealth from Nature's deep storehouses.

IN THE twenty-five years since *Coal Age* was founded, the industry has passed through three major economic phases which, in turn, have influenced the direction of engineering progress. Expansion was followed by liquidation and liquidation by a depression which struck at all industry. Today, readjustment and recovery are the economic watchwords. And the question is raised whether it is better that coal meet the problems of the new day as a completely self-governing entity or under Washington supervision. This is neither the time nor the place to debate that question. But one incontrovertible statement can and should be made: Any system—internal or external—which attempts to penalize efficiency either through control of distribution or price-fixing spells disaster.

BECAUSE it is easier to dramatize an epidemic than an antitoxin, catastrophe can always make the front page. In the casual reading of business history, popular attention usually is centered upon the ills of industry, the disasters and the disputes which occasionally flame into industrial warfare. And coal men, not unlike some of their brethren in other industries, have helped to color the picture by advertising their troubles more freely than their achievements. As a result, many outsiders have come to look upon coal mining as a medieval industry sadly out of step with the spirit of the times.

SOBER STUDY of the actual progress made in modernizing methods, equipment and policies during the past quarter of a century, however, reveals a record of accomplishment of which any industry might well be proud. Better understanding of this record should be a spur to further achievement and should go far in dispelling popular misunderstanding of the industry's place in the American picture. This record is the theme of the pages which follow.

ECONOMIC STATUS OF COAL-MINING INDUSTRY IN LAST QUARTER CENTURY

THE ECONOMIC picture of the coal-mining industry has been rich in startling and fundamental changes during the quarter of a century since *Coal Age* first saw the light of day. While the great technical advances made in that period for the most part have been orderly and evolutionary, changes on the economic front frequently have been violent, widespread and quick. In many cases, these changes swept away cherished bench-marks—such as the decennial doubling of bituminous-coal production—and impaired or destroyed the value of others for gaging the progress of the industry. New bench-marks, therefore, are necessary for a proper perspective on the present economic status of coal mining.

During these 25 years, the bituminous branch of the industry has passed through three distinct phases. Back in 1911, the soft-coal mines were still riding on the crest of the industrial expansion that began with the metamorphosis of the United States from an agricultural to an industrial nation. Expansion in the coal industry itself was further accelerated by railroad building into new producing fields, the encouragement given to developments in non-union districts, recurring transportation difficulties, strikes and threats of strikes, wide variations in both seasonal and annual consumer requirements and, finally, by the extraordinary and abnormal demand for coal thrown upon American mines by the World War.

Excess Had Unsound Basis

Under the conditions which existed during the early years of the present century, maintenance of a large excess mine capacity was essential to assure a full fuel supply. Many of these conditions, however, were either impermanent or unsound and carried the seeds of their own destruction. Periods of high prices and scarcity stimulated further mine development, widened the opportunities for competitive fuels and gave fresh impetus to the movement for the more economical utilization of coal by large industrial, railroad and public-utility consumers. Transportation service was improved; car shortage as the term had been known in earlier years joined the obsolescent class. The power of organized labor in the coal fields, which had reached a new peak during the War, was curbed; strike threats and actual suspensions in the strongly unionized districts no longer terrified the consumer.

Deflation Far-Reaching

As a result of these changes, at the time when the country as a whole was entering upon the Coolidge boom period, the bituminous-coal-mining industry was starting an era of deflation and liquidation. Between 1923 and 1929, the number of commercial bituminous mines in operation was cut from 9,331—the all-time high—to 6,057, and the potential capacity (on the basis of 308 working days per annum) from 970,000,000 to 752,000,000 tons. The number of men employed declined from 705,000 to 503,000. Those fortunate enough to remain on the mine payrolls, however, enjoyed better working time, as the average number of days the mines operated rose from 179 to 219 per year.

Although this liquidation record usually is one of the prize exhibits offered by those who contend that coal is a dying industry, the facts of the case do not bear out that ghoulish interpretation. The 1923-1929 liquidation was caused primarily by the disappearance of the conditions which had made the maintenance of an excessive reserve capacity necessary in earlier years to offset the effects of railroad disabilities and labor disturbances. With the elimination of those conditions, many mines which could be operated profitably only during brief periods of exaggerated demand and high prices were forced out of the picture; companies with a large number of mines concentrated production at their lower-cost operations.

Bituminous coal output in 1929 was only 30,000,000 tons less than in 1923—the year selected by the U. S. Bureau of Mines as the yardstick by which to measure current production statistics. This decline of 30,000,000 tons, however, was less than the savings effected by the railroads and public utilities through increased efficiency in the utilization of coal. Actually, therefore, there was no shrinkage in effective demand: the worst which justly might be said of the 1929 record was that coal was not securing its full share of some of the newer business which had developed in the national energy market since 1923.

Under the impact of the general industrial depression that started late in 1929, bituminous coal suffered further losses. At the bottom, in 1932, the number of active commercial operations had been cut to 5,427, the working force had shrunk to 406,000 men. The average number of days operated had dropped to 146—the lowest average touched at any time during the present century except in the great strike year of 1922, when mines in the old Central Competitive Field and many outlying districts were idle for nearly five months. Financially, too, the industry took on a redder tinge, with corporate losses, according to federal income tax returns, rising from $11,822,000 to $51,167,000.

Upswing Begins in 1933

Unlike the 1923-1929 liquidation, which was largely the result of the operation of internal forces, the 1930-1932 declines were directly due to external pressure. As that pressure lightened, a modest upswing began. By 1933, the number of active commercial operations had risen to 5,555 and the number of men employed to 419,000. Comparable data on the number of active commercial operations the past two years are not available, but private surveys (*Coal Age*, February, 1936, p. 73) and current news reports both show a definite revival in new mine development. The financial picture improved slightly in 1933, when net losses were cut to $47,549,000, and still more sharply in 1934. Due in part to increased demand and in part to the adoption of the 35-hour week in 1934, employment also has increased; preliminary estimates place the number employed last year at 462,000.

That this earlier internal liquidation also helped the coal-mining industry to withstand the shock of the later general depression is indicated by the comparative records of coal, other mining and the manufacturing industries during the early '30s. In 1932, the gross income of

the manufacturing industries shown in income tax returns had dropped to 44.33 per cent of the 1929 total, while bituminous coal gross income in 1932 was 46.59 per cent of its 1929 total. The gross income of the anthracite division of the industry was slightly higher in 1932 than in 1933 and in the latter year was 82.49 per cent of its 1929 total. By 1933, gross income for the manufacturing industries had risen to 48.73 per cent of the 1929 total; gross income for bituminous mining enterprises was 51.48 per cent of the 1929 figures—and production was approximately 69 per cent.

Comparative records for other divisions in the mining and quarrying group also give bituminous coal a slight edge in most subgroups and a distinctly better showing than metal mining during the depression years. Gross income for the oil and gas subgroup in 1932 dropped to 44.54 per cent of the 1929 figures; the subgroup designated "other minerals" (asbestos, clay, granite, precious and semi-precious stones, salt, etc.) fell to 41.79 per cent; miscellaneous mining and quarrying, including lessors and holders, was 43.67 per cent. The collapse in metal-mining values cut the 1932 gross income for that subgroup to 13.28 per cent of its 1929 total.

Treating each of the three phases—expansion, liquidation and depression—through which the bituminous division of the coal-mining industry has passed since 1911 as a separate entity, the pattern for each phase does not appear unduly irregular or startling. Change becomes vivid when isolated yearly comparisons are attempted. Thus, during the past quarter of a century production climbed to 579,000,000 tons in the war year of 1918 and plunged to 310,000,000 tons in the depression year of 1932—the smallest total in any year since 1904. And on the financial side there is the picture of 1,234 companies showing a combined net income of $632,-281,417 for the five-year period 1917-1921 and the industry as a whole reporting a total loss of $204,354,075 in the five-year period 1929-1933.

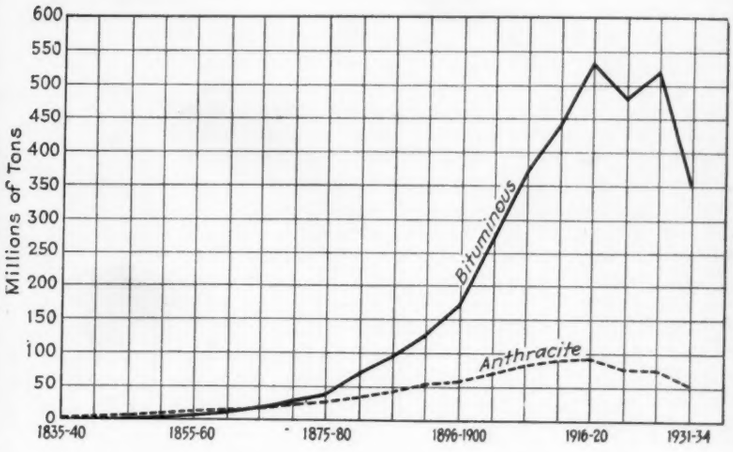
Such contrasts are so dramatic that they can easily be misleading and distort or obscure the more fundamental changes which have been taking place in the economic status of the industry during the past quarter of a century. Analyses of these basic changes, however, all point to one conclusion: In less than a single generation the soft-coal industry has been transformed from a speculative venture dependent upon abnormal conditions for large, short-term profits into a business which must rely upon regular movement, low costs and modern merchandising methods for its future financial success. Today is the period of readjustment to meet new conditions.

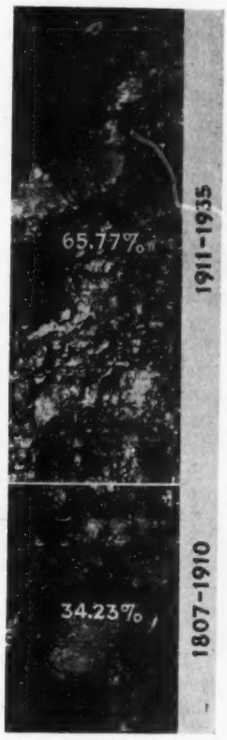
Because the industry as a whole is still primarily production-minded, it naturally thinks first of readjustment in terms of tonnage. Will annual output again move sharply upward or must the industry reconcile itself to a gradual shrinkage in volume? If the trend is to be upward again, what rate of increase should be considered adequate and satisfactory? Although categorical answers to speculative questions are frequently as dangerous as prophecy, certainly there is nothing in the record of recovery since 1932 to suggest production levels have been anchored. Each year since the low point in the depression has shown an increase. Cumulative production to Sept. 12, 1936, was 77 per cent of the corresponding total for 1929 — which compares more than favorably with indices of general business activity at this time.

When the question turns on the rate of future increase, however, both the shadows of obsolete yardsticks and the imperfections of newer gages intrude. These shadows cannot be ignored, for their psychological effect has been evident in many of the pessimistic appraisals of the future of the industry which have been published in recent years. For half a century (1870-1920) bituminous production roughly doubled every decade. To expect that rate of increase to continue was, to say the least, fantastic, since it would have set the 1930 level at 1,138,-

A Century of Coal Production

In the chart below average, annual production for each five-year period from 1836-1840 to 1931-1935 is shown. The quinquennial basis has been used to smooth out frequent abnormal variations in the output of two successive years due to temporary causes such as strikes, since the loss in a strike year usually is offset by abnormal increases in the year immediately preceding or following. The coal bars to the left and the right of the chart show graphically the percentage of the total tonnage mined since 1807 produced in the past quarter of a century. The bar at the left represents anthracite output; that on the right, bituminous.





000,000 tons! The fact that production the past five years was 67.5 per cent of the total for 1925-1930—a period which has the second largest quinquennial output in the history of the soft-coal industry—seems much more significent and inspiring.

Leaving speculation for actualities, it is obvious that three factors will control the rate of increase in annual bituminous production. These three factors are: (1) the speed of general industrial recovery and expansion, (2) the efficiency in the utilization of coal by large consumers, and (3) the growth of the use of competitive sources of energy. The record of the past five years shows the close relationship between coal production and industrial activity; tonnage has increased as business has revived and that trend is continuing.

Efficiency Cuts Consumption

In the last 25 years, efficiency has played a major part in reducing coal consumption. Since 1917, for example, there has been a reduction of 57.9 per cent in the unit consumption of coal per kilowatt hour in public utility plants, 31.8 per cent in unit consumption in railroad freight service, 20.1 per cent in railroad passenger-train service and 19.5 per cent in consumption of coal per gross ton of pig iron and ferroalloys. These three groups alone accounted for 44 per cent of the industrial consumption last year—and efficiency was not limited to that trinity. In recent years, however, the rate of increase in efficiency of utilization has slowed down: with shorter trains at higher speeds, an increase in unit consumption by the railroads is predicted.

Coal also has lost markets to oil, natural gas and water power. The losses to oil and natural gas usually are exaggerated in the public mind and those to water power underestimated. This misunderstanding arises from the common failure to make the proper allowance for the fact that government statistics on energy supply cover the entire output of crude petroleum and natural gas. As the U. S. Bureau of Mines has repeatedly pointed out in presenting these figures, "nearly half of the natural gas is used in the field for drilling or operating oil and gas wells and pipe lines and for the manufacture of carbon black. More than half the oil is used in the form of gasoline, kerosene and lubricants." No small part of the output of both oil and gas is consumed in areas, such as California and portions of the Southwest, "where coal is available only at unusually high cost because of heavy transport charges." In this article, however, such California and Southwestern consumption is treated as strictly competitive with coal.

If the non-competitive uses are eliminated from the picture, coal's percentage of the national energy market last year is raised from 51.6 per cent (anthracite, 6.5, and bituminous, 45.1 per cent) to 63.8 per cent (anthracite, 6.0, and bituminous, 55.0 per cent); the percentage credited to water power is increased from 10.3 to 12.7 per cent. Even at the lower figure (51.6 per cent), "coal," states the 1936 *Minerals Yearbook*, remained the largest source of energy in 1935." Moreover, since the oil and gas industry showed even heavier deficits than the combined total for anthracite and bituminous coal ($220,590,311 against $209,590,765) during the 1930-1933 period on a gross income less than 55 per cent of the total for coal, the advantage is not all on the side of coal's competitors.

Situation Should Be Faced

Because the situation does not appear as dark as it has sometimes been painted, however, does not mean that either the present actualities or the potentialities of competition from other mineral fuels and from water power should be minimized in mapping the future course of the coal industry. Bituminous production last year was 163,000,000 tons under the 1929 total: probably 31,000,000 tons of this represented losses to rival sources of energy, possibly actual increases in consumption over 1929 figures by some coal-consumer groups may conceal additional losses. Over 7,300,000 tons of the 31,000,000 may definitely be assigned to gains by competitive sources of energy in the public-utility and bunkering markets. Oil, of course, is wholly responsible for the decline in the consumption of coal for bunkering; while both oil and gas have gained in the public-utility field, water power has been the chief beneficiary of recent shifts there.

Whether government control is necessary or desirable in an orderly readjustment of the economic functioning of the industry is hotly debated. The question is not new or even peculiar to the last quarter of a century, but that period, however, has punctuated academic discussion with actual experiments. Back in the early winter of 1914, Illinois and Indiana operators were asking Washington to take official cognizance of their difficulties and in the spring of 1933 spokesmen for these same States were again at the national capital suggesting legislative aid. The first major venture in actual regulation was taken during the War when the U. S. Fuel Administration assumed control of prices, distribution and wages. Between the demise of that agency and the creation of the National Recovery Administration, there were a few minor experiments. Attempts to carry on regulation since the death of NRA so far have been halted by the courts.

Basis of Control Shifts

The primary purposes of the war-time control and of the NRA regulation were directly opposite. In the former, the objective was to put a ceiling over prices and protect the fuel supply of essential consuming industries. Under NRA, the major objective was to put a bottom under prices to support wage scales and to protect the coal industry from the effects of uncontrolled distribution. The abortive Bituminous Coal Conservation Act of 1935 promised a regulatory system closely paralleling that exercised by NRA, with definite labor participation in the administrative councils and an open effort to control distribution through price fixing.

War-time control unquestionably acted as a brake on increasing profits in the sale of coal in an abnormal market. Income tax returns for 1,234 identical companies accounting for at least half of the output at that time dropped from $203,918,518 in 1917 to $148,846,632 in 1918. Comparative income data for 1934 are not yet available, but published reports for individual companies indicate rising income despite increased wage rates and shorter hours and a demand that was only 64.2 per cent of estimated capacity on the basis of 280 days' operation per year. The 1918 output, on the other hand, was 80 per cent of potential capacity estimated on the basis of a 308-day year.

Those opposed to government supervision fall into two categories. One group holds stoutly to the belief that competition should be subject neither to governmental nor official intra-industry restraints. Such freedom of action prevailed throughout the 1923-1929 liquidation period. The second group favors self-government through agencies such as Appalachian Coals, Inc., where the tonnage of member companies can be marketed without ruinous

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A QUARTER CENTURY
BEFORE—AND AFTER

By HOWARD N. EAVENSON
Eavenson & Alford
Pittsburgh, Pa.

THE QUARTER CENTURY 1911–1936 is only a little less than one-sixth of our national life and about one-third of the time elapsed since the bituminous coal indutry began to loom large in our industrial development, but it has witnessed greater technical changes than occurred in all the time before and some profound economic changes whose importance has not been appreciated fully by many in the industry. The beginning of this period, though none knew it then, was nearly at the end of the production-doubled-in-every-decade cycle, which had lasted more than sixty years; then came the tremendous increase of the War period, 1918–1926, and the steady recession to 1932, and perhaps this year will again see an output as large as that of 1911.

In 1911, the per-capita consumption was 4.4 tons; it reached its peak in 1918 at 5.6 tons, while now it is little more than two-thirds of the 1911 figure. At the beginning of this period the production of fuel oil was about 15 per cent of that at its end, and the natural gas produced in 1911 was about 30 per cent of that produced in 1936. Truly, the increases in fuel-oil and natural-gas outputs and technical improvements in coal combustion have played havoc with bituminous coal in the last quarter century.

Machine Types Change

Technical developments in the industry during the period have been many, most of them changes in what was being used, but a few that are entirely unlike any in use before. In 1911 the change from the older types of mining machines to shortwall machines was well under way, although only 9 per cent of the total number of machines in use were shortwall and longwall types and almost 90 per cent were breast and pick machines. Now these two types can be found only in museums and the number of shortwalls being installed is not much greater than that of mounted machines cutting from the track.

Cutting has become quicker and much less laborious, and much of it is now done at various heights above the bottom and in or under partings to facilitate cleaning. Shearing was nearly unknown in 1911; now many mines both undercut and shear, to reduce explosives cost and protect the roof. Now, while about 1,900 fewer machines are in use than in 1911, over one hundred million tons more coal is machine-cut, the percentage of total production having increased from 44 to 79. Much drilling is done now by mounted machines, as contrasted to the old breast auger.

One of the greatest changes in this period has been the introduction of mechanical loading. Prior to 1911, with the exception of a few experimental loading machines and conveyors, all coal had been loaded as it had been for hundreds of years: by shovel and man strength. None of the many mobile loaders which had been invented was in more than experimental use, nor were any conveyors being used. Since then a number of each type of machine have been perfected and both mobile loaders and pit-car loaders were quite largely in use in Illinois—on account of the high wage rates—a number of years ago. Since the wage advances in the Eastern fields, beginning in 1933, the advance in the use of both forms of mechanical loading has been rapid and 1936 will see about fifty million tons of bituminous coal loaded this way, or about 13 per cent of the total production.

The installation of these machines has materially reduced the manual labor required, has changed the competitive situation between mines, has materially increased the output of the mines using them, as most of them operate multiple shifts; has reduced the number of loaders, and increased the average pay of the employees. Incidentally, the use of mobile loaders almost requires mechanical cleaning of coal, and is largely confined to the thicker seams and better seam conditions, while the conveyors are used in the thinner seam mines.

Not much progress has been made in mining methods during this period, as far as longwall or longface working is concerned. Such methods have been tried in many seams in different fields, but probably not as much coal was produced by them this year as in 1911. During this period, however, several methods of concentrated mining were developed, due to the faults of the old panel system, and these have effected great economies in haulage, trackwork, ventilation and in development expense.

One of the largest savings that can be made by mechanical loading, of either type, is that due to the concentration of working places, because of the greatly increased output per place, caused partly by mechanical loading and partly by multiple shifting. In this respect conveyor mining, where also a conveyor is used on the room heading, bids fair to secure equal economies with the mobile loader and without necessitating mechanically cleaning the coal. Practically no mines have yet realized the full benefits of such concentration. With the exception of mines in Illinois, few mines have yet changed their organizations sufficiently to reach the increased tempo demanded for the best results in mechanical loading.

Coal Recovery Down

There has been little, if any, progress in the recovery of coal in mining, and probably, due to the long depression and low prices prevailing in the industry, the percentage of actual recovery is less now than in 1911. While under some conditions mechanical mining, due to its faster extraction and greater concentration, should improve the recovery, in some cases it has been found that the increased costs of pillar removal are more than the value of the coal left, and the economic answer will overcome the desire to recover all the coal possible which nearly all mining men have. This condition can be changed only when the margin of profit is enough to provide for the extra costs of maximum recovery, if more than the methods used.

In the transportation from the face to the tipple many changes have occurred. In 1911 nearly all coal was gathered by animals; now most of it is being done by haulage motors and in practically all mines opened within recent years gathering motors have been installed. During the period, gasoline-engine gathering and haul-

age motors came and went, and to avoid cable and reel troubles the storage-battery locomotive was applied, first to gathering coal and then in some very gaseous mines to main-line haulage, making, with storage-battery tanks for cutting and pumping, wireless mines. In 1911 there were a number of compressed-air haulage locomotives in service, but these, on account of expense, have been superseded by electric locomotives in all but a very few mines whose life does not warrant the change. In electric-haulage locomotives, development has been toward heavier, faster machines with contactor control and fans on the motors; some units weighing 45 tons and pulling 400 to 500 tons of coal per trip at fifteen miles or more per hour are being operated.

Development in mine-car construction has been rapid. In 1911 there were few cars in use holding over three to four tons; now there are many carrying five to six tons and few new mines install small cars. Modern cars usually are of steel, built low to avoid unnecessary labor in lifting coal, with roller bearings, spring draft gear and in some cases with automatic or semi-automatic couplings. They cost less for repair and greasing, spend a small fraction of the time in the shop the old ones did, last from two to five times as long and have an initial cost from four to seven times that of the 1911 cars.

Belts Enter Haulage

During this period two captive mines have installed conveyor belts for main haulage. These are about four miles long and the coal is hauled to the inside dump in the usual way, the transfer from one belt to another being automatic. Such installations are expensive, but, when tonnages of over 8,000 per shift are wanted, have proved more economical than the older methods.

To meet these developments in motors and cars, modern mines use 60-, 70- and even 90-lb. rails on main haulage, heavier rails on room headings and in rooms, and nearly always steel room ties. Wooden rails in rooms are a curiosity, instead of the usual thing, as in 1911. Track welding, instead of bonding, is increasing, and alignment and grades are much better than in 1911. Signal systems and dispatchers are used at many mines. Voltage of direct current is very largely 275—many States will not allow more—and 6/0 and even 9/0 trolley wires are largely used. Most modern substations have been made automatic, to eliminate labor costs, and within the past year several mercury-rectifier units have been installed in mines and bid fair to be more economical than the older machines.

In nearly all main stations centrifugal pumps have practically superseded the older types, but these are not very successful as gathering units. Mine fans are nearly all electric, run at higher speeds and are more efficient than the older types. In 1911 it was the best practice to install initially a ventilating plant of the ultimate size required; now better practice is to design the system to use a small unit at first and to replace this when requirements increase beyond its capacity; in this way an efficient plant can be maintained at all times and the ventilating cost be largely reduced.

In 1911 little, if any, bituminous coal was produced by stripping; the first reports of strip coal were made in 1914. Technical advance in this form of mining has been unusually rapid, and the early forms of contractor's equipment have been superseded by electric shovels having bucket capacities as large as 32 cu. yd. and an operating cycle of one minute or even less. In some cases enormous tractor trucks have replaced cars and tracks for haulage of the coal. More than 450 shovels are operating in strip pits and more than twenty millions of tons annually is produced by them.

Oil Lamps Vanish

In 1911, while many carbide lamps were in use, most mines were lighted by oil and flame safety lamps. Now, except for special uses, no oil lamps are used and carbide lamps have replaced them. Few flame safety lamps are used, except for test purposes, as the development of the electric lamp has produced one giving many times the light at the same cost. In fact, many open-light mines are using the electric lamp, rather than the carbide, on account of the better illumination provided. Conveyor mining conduces to the use of flood lamps, and some mines have their entire haulageways lighted by electric bulbs, with current from special wires or the trolley wires.

Since 1911 the development of safety methods in mining has been marked. Rock-dusting was not known then, and its introduction has nearly eliminated gas and dust explosions, and even where they start, their extent and severity are greatly reduced. The educational work of the U. S. Bureau of Mines, the passage of compensation laws and the increasing costs of accidents have all helped to reduce their frequency, although there is still a long way to go before the minimum is reached. During the period the number of fatal accidents has decreased from 3.53 to 1.98 per thousand employees and the tonnage per fatal accident has increased from 207,000 to 407,000. Fatalities per thousand employees from dust and gas explosions have decreased 90 per cent; from falls, 40 per cent; from haulage accidents, 24 per cent, and from explosives, 78 per cent.

HOWARD N. EAVENSON

Senior member of Eavenson & Alford and past president of the American Institute of Mining and Metallurgical Engineers, has been intimately associated with coal mining since he was graduated from Swarthmore in 1892 and started work as a draftsman and transitman in Wise County, Virginia. Prior to engaging in consulting practice in 1920, Mr. Eavenson was successively division and assistant chief engineer, H. C. Frick Coke Co.; division engineer, Pittsburgh Coal Co.; chief engineer, Continental Coke Co., and chief engineer, United States Coal & Coke Co., Gary. In addition to his consulting practice, he also is president of the Clover Splint Coal Co.; vice-president of the Boone County Coal Corporation and a director of the Pittsburgh Coal Co. He played a prominent part in the organization of Appalachian Coals, Inc., and Bituminous Coal Research, Inc. Mr. Eavenson has contributed a number of outstanding articles to the technical press and to the programs of the engineering societies; he also is the author of a delightful series of lectures published under the title of "Coal Through the Ages."

Since 1911 the use of explosives has tended to the permissible types, which have largely replaced black powder and dynamite. Recently Cardox and Airdox have been introduced, and both have many desirable safety features.

The preparation of coal outside the mine has now progressed to limits undreamed of in 1911. Saving of labor by the use of rotary dumps has been large; loading booms and picking tables are the rule and not the exception; most new tipples are steel instead of wood; bar screens have been entirely replaced by shaking screens, and vibrating screens are very largely used, especially for the smaller sizes; in fact, one or two tipples have been designed to use vibrating screens throughout. Much more sizing is done now than ever before. Dry tables, Rheolaveurs, Chance cones and air-sand cleaning methods are all new, and largely used, and many improvements have been made in other processes.

Some central plants, to clean coal assembled from several mines, have been built, and with the installation of mechanical loading many new cleaning plants are necessary. Some of the large wet cleaning plants have elaborate drying systems for the fine coal, this being particularly true when the coal is for metallurgical purposes. About three and a half times as much bituminous coal was mechanically cleaned in 1936 as in 1911.

Manual Labor Lessened

All of these technical developments have greatly lessened the manual work required in producing coal, and made it more of a job operating machines. The tons produced per man on payroll per day in 1935 was 4.40, as against 3.50 in 1911, and per year the tonnage was 785 as against 738. About 100,000 fewer men, or 18 per cent, were employed in 1935 than in 1911, and they averaged 178 days work, as against 211.

The size of mines has increased largely during this period: in 1911, 1,361 mines, each producing over 200,000 tons, accounted for 72.5 per cent of the total output, whereas in 1935, 1,036 mines of the same class produced 80.5 per cent of the total; 129 of these mined over 500,000 tons each, or 26 per cent of the total. One tipple with two mines will produce almost three million tons this year; in 1934, eleven mines produced between one and two million tons each, averaging 1,127,000 tons. In spite of this, however, there were a total of 5,887 mines, averaging 68,749 tons, in 1911, and 6,258, averaging 57,425 tons, in 1934, a considerable part of the difference being due, however, to the fact that many more of the small trucking mines were included in the later year's figures.

Generally it is true that technical progress in the last quarter century has all tended to the reduction of the amount of hard labor required and substituted the operation of machines; toward the installation of much better and more expensive machinery and of more complete and costly plants. Another great change is in the growing appreciation by operators of the value of research, both applied and scientific, to the industry, and a willingness, when able, to contribute toward it. The money available is only a small fraction of what should be spent, but, unless this industry differs from all others, it will help to change it greatly in the coming years.

What developments will occur in this industry in the next quarter century? For several thousands of years there has been available some excellent advice about prophets, but one can possibly be pardoned for drawing conclusions from trends in the past. It is reasonable to think that if wage rates remain at the present levels, or are increased, there will be extensions of mechanical mining in every mine where physical conditions warrant and financial ones allow; that such mines will work practically continuously to fill the steady demand, and the peaks will be taken care of by the older type mines; that these mines will have larger mine cars, hauled by internal-combustion locomotives, doing away with the bothersome and dangerous trolley wires, and allowing better voltage to be supplied mining and loading machines and pumps by a.c. circuits, with better lighting and operated by men better trained for their work than most mine officials are now.

Such mines will be much safer than present ones, and the accident rate will be greatly reduced. The product will be better prepared, and, through better knowledge of the requirements of consumers and of the character of the coal, it will be better adapted to its uses. If, as is expected, the supply of the liquid fuels has begun to decrease before that time, much of the product will be used by automobiles, and this increased demand should make the bituminous-coal industry a much better one than during the period just passed.

MINING METHODS AND MECHANIZATION

THE MINING of coal, in its essentials, involves breaking down a solid stratum of material into sizes suitable for handling and then loading it into or onto suitable equipment for transportation to the surface. As coal is won, a fresh face of solid material is presented, and laying out a mine involves arranging for a continuous supply of such faces with an aggregate length sufficient, with the normal rate of advance, to give the required tonnage per shift.

After the coal is broken down (see p. 408 of this issue), the next question is loading. When mining started, this task was delegated to the man with the shovel, and he still accounts for most of the output, although comparatively recently, considering that mining started in the United States about the middle of the 18th century, his dominance in this field has been challenged by the machine. Use of the machine to add to the power of man's muscles is less than 60 years old in this country, and only in the last 25 years has it begun to make real progress.

Using his pick and shovel, the early miner attacked the coal at the outcrop. In fact, early mining was practically stripping, as the openings got little beyond the sun. Exhaustion of outcrop coal, however, forced a change to the forerunners of present deep-mining methods, and as early as the 14th century in England coal was being mined by shafts and adits.

Early shaft mines, or "bell pits," were, however, little more than wells a few feet deep near the outcrop, widened out at the bottom to permit extraction of the coal as far as the roof would stay up. Then a new shaft was sunk. Later, as depths

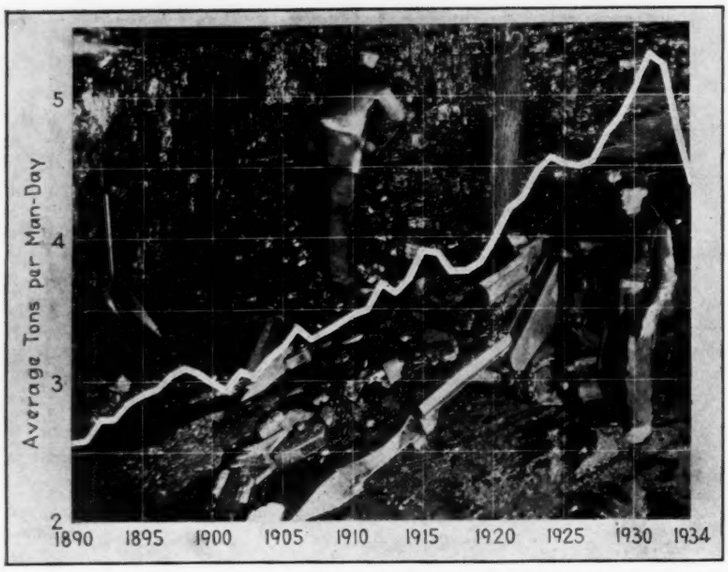


Fig. 1—Aided by the increased use of machinery, the daily output of the bituminous miner has been steadily upward since 1890

increased, galleries were driven and pillars were left for support. Although the galleries permitted mining much larger areas, comparatively speaking, workings still were limited, and until the Newcomen atmospheric engine (1710) made steam pumping possible, shafts were rarely over 300 to 350 ft. deep and the area worked from one shaft was seldom over 600 ft. in radius.

Leaving pillars for support logically resulted in the "bord-and-pillar," "bord-and-wall," "post-and-stall" or "stoop-and-room" systems of mining, corresponding to the "room-and-pillar," "chamber-and-pillar" and "breast-and-pillar" systems in the United States. When pillar extraction was first practiced is unknown, but it seems certain that pillars were mined in the north of England before 1740. Early pillar extraction was confined largely to the shallower non-gaseous mines, as ventilation improvements, development of a mine light safe in gas and leaving larger pillars as a means of preventing creeps and squeezes, permitting pillar extraction in the deeper and more fiery operations, were later developments. Pillar extraction on second mining was not generally accepted until early in the 19th century, which also saw the start of longwall on an extensive scale.

Early mining naturally was accompanied by a low percentage of extraction. In the deep collieries of the Tyne, for example, the maximum percentage until about the end of the 18th century was considered to be 45.5. In 1795, Thomas Barnes, viewer at the Walker colliery, divided the coal into 10- to 20-acre sections separated by pack walls 120 to 150 ft. thick to prevent squeezes from spreading and thus made possible higher extraction. Early in the 19th century, John Buddle, Jr., Wallsend, adopted splitting of air currents to improve ventilation and developed a modification of Barnes' isolation method using coal pillars as barriers, thus originating the panel system of working (used in starting the Wallsend G pit, 1810).

Anthracite is believed to have been mined by the Indians as early as 1744, and bituminous mining is believed to have started near Richmond, Va., about the same time. Mining systems paralleled rather closely British developments, not only because logic favored this course but also because this country early drew on England, Scotland and Wales for mining men. Operations at the Summit Hill (Pa.) property of the Lehigh Navigation Coal Co., where Philip Ginter discovered coal in 1791, offer an example of the course of early mining. Recovery was first based on quarrying. Then, as operations went deeper, the breast-and-pillar system was adopted.

Chute-and-pillar or breast-and-pillar (steeply pitching beds) and chamber-and-pillar (light-pitch beds) systems still are standard in the anthracite region, supplemented by an increase in long-face methods in the last 25 years, primarily in connection with conveyors and scrapers in thin coal, and adoption of a number of special methods in very thick, highly inclined beds. Early gangways and airways were driven in the coal, and this still is general, especially in thin and light-pitch beds. With thick and highly inclined beds, however, driving in the coal in many cases involves keeping openings for long periods, with excessive maintenance due to roof and timber deterioration and pressure. Consequently, a number of companies have transferred gangways or gangways and airways to the rock or a thin bed below that being mined, working the coal from rock chutes.

Reducing cost of reopening old workings and maintaining roadways and airways thereafter was the principal reason for the initial adoption of driving in rock. About 1891, when the 4th and 5th levels, Coaldale colliery, Lehigh Navigation Coal Co., were opened, gangways were made in the thin Skidmore bed beneath the Mammoth, which was explored and mined from rock chutes. Later, rock gangways were used to mine virgin coal, supplemented by panel tunnels driven off the rock gangways to strike the bed. From these tunnels, short panel gangways were driven in the bed. Life of the panel consequently was limited, preventing undue deterioration of the panel gangways. With further improvement in drilling methods and explosives, the trend toward rock or thin-vein development has strengthened at Lehigh Navigation properties, and now gangways and airways usually are placed below the bed, which is tapped by rock chutes. Other anthracite companies have adopted substantially similar systems.

Silting Enters Picture

While cost or mining difficulties dictated leaving coal pillars in many mines in earlier days, the major incentive in a number of instances was support of the surface or overlying beds. Mining such pillars naturally requires an artificial roof support, which has led in some cases to flushing, silting, or backfilling. Although a mine fire had been silted as far back as 1884, one of the earliest examples of backfilling for surface support was at the Kohinoor colliery, Shenandoah, Pa., 1887. John C. Haddock used silt to flush open spaces in the Dodson colliery. Plymouth Coal Co., in 1891, prior to pillar recovery.

Silting was reported to be fairly common in the Northern anthracite field about 1920, with the Kingston (Pa.) Coal Co., a leading exponent of the method, the material most often consisting of crushed breaker refuse flushed into the mines through

pipes. In 1932, hydraulic backfilling was started at the Richmond No. 3 colliery, near Scranton, with material obtained from a gravel pit near the shaft head. Chambers and other openings were first flushed, then the pillars were mined and the spaces thus created were filled, completing the operation.

As in anthracite, soft-coal mining was soon characterized by general adoption of the room-and-pillar system, corresponding to the hard-coal breast- and chamber-and-pillar systems. It seems evident that comparatively crude development plans survived in many fields until fairly recently, as W. M. Morris, in a letter to *Coal Age* in 1915, stated that he had instituted the multiple-heading plan in Illinois in the early 80s. Before this system became general, mining evidently had evolved the single-heading system, in which doors were placed across the mouth of each room to establish a return. Mediocre or no ventilation was the inevitable result, so that as working areas were extended and mines became larger, the multiple-heading system providing intakes and returns in parallel headings was adopted through necessity. With its establishment, development methods gradually evolved into the main-, cross- and room-entry systems of today.

Concentration Early Used

Concentration, a common term of today, had its roots in the 80s or 90s, but apparently the idea had gained but little ground by 1910, when a new mining system, based on the extraction of large blocks, was installed in the Bridgeport (Pa.) mine, H. C. Frick Coke Co. Developed by Patrick Mullen, W. C. Hood and Jacob Gates, the system provided for driving rooms only as needed and extracting the blocks immediately on a continuous pillar line. A striking feature was the use of mining machines in pillar extraction to increase output from a single place and thus achieve concentration.

Longwalling, or long-face working, another concentration method, was early discussed and sometimes tried at bituminous mines. Some authorities in 1911 even foresaw its eventual use by most of the industry. This end is yet to be attained, although longwall working is common in Illinois District 1, northwest Missouri, northeast Kansas and the Osage district, the Appanoose field, Iowa; north central Texas and the Canyon district, Colorado, with scattering applications in other fields. Aside from the above districts, longwall, or long-face, has in most cases been tied to conveyor or scraper mining. And even with the latter equipment there is a noticeable tendency at present toward the room-and-pillar system.

Bituminous mining has been accompanied by a seldom-interrupted rise in daily output per man employed, with the result that in 1934, according to U. S. Bureau of Mines figures, the average production per man per day was 4.40 tons, against 3.50 tons in 1911 and 2.56 tons in 1890. In 1934, however, the industry changed to the 7-hour day on April 1. Previously the 8-hour day was in effect at most mines as a result of the gradual adoption of the 8- instead of 9- or 10-hour schedules from about 1898. Per-man output in the anthracite industry has fluctuated considerably between 1890, with an average of 1.85 tons, and 1934, with an average of 2.53 tons.

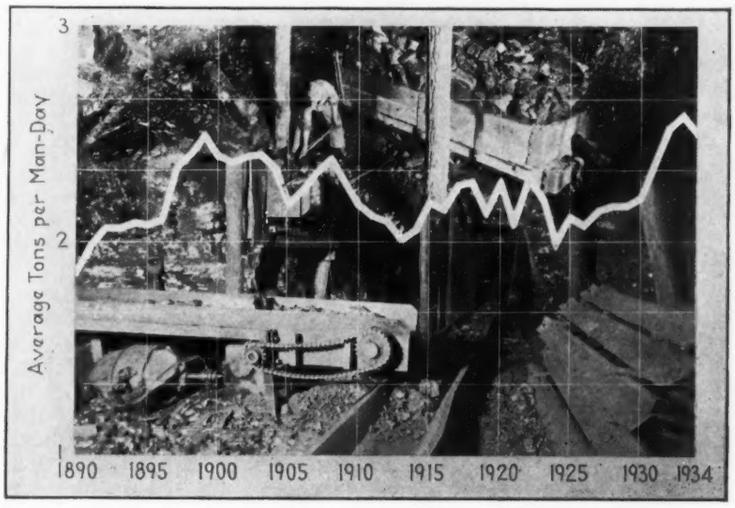
Chief credit for this increase in individual output in both industries, one of the major reasons why coal has remained a relatively cheap product, is the spread of machinery in practically all departments of mining, including stripping, coupled with improvements in design to raise unit capacity and increase continuity of operation. As a corollary, investment per man employed and per annual ton of output has been materially increased to maintain tonnage per man-day.

The first loading equipment in the United States, available records indicate, was a Stanley header brought over from England and tested in the Franceville mine, near Colorado Springs, Colo. The coal broken down by the machine, however, was loaded by hand. In 1890, a Stanley header with conveyor was installed in the Bennett mine, Lebanon, Ill. In 1893, experimental work was begun on a loader first known as the Jones (from James Ellwood Jones, Pocahontas Fuel Co.) and offered for sale as the Coloder in 1925. In 1902, a patent was issued on the principle employed in the first commercial units, installed in Pocahontas Fuel Co. mines in 1918. In developing the Coloder, the idea apparently was to make a loader only, whereas most early designers concentrated on machines that also would break down the coal.

The affinity between long faces and conveyors dates back many years, and it was the difficulty of handling coal after it had been brought down on a long face that was responsible for the development of the coal-face conveyor, ascribed to the joint efforts of Clarence R. Claghorn, an American mining engineer, and W. C. Blackett, manager of a County of Durham coal mine. The initial impulse came from a search for a more efficient means of conducting long-face work at the Vinton Collieries Co., Vintondale, Pa., where the first chain-and-flight units were installed in 1902.

The first mobile loader on the market was the Hamilton, installed in the Dewmaine (Ill.) mine, St. Louis & Big Muddy Coal Co., in 1903. This machine employed the "sweep-chain" gathering principle, a continuous chain with flights running down around the nose of the unit to dig out and pick up the coal. Use of the Hamilton loader, reported to have averaged 150 tons per day, brought out what is still the major problem in mobile-loader operation:

Fig. 2—Fluctuations characterize per-man per-shift output of anthracite miners since 1890, with machinery playing a large part in the upward trend in late years



keeping up cars. Jeffrey acquired the Hamilton patent rights in 1913, and from them N. D. Levin developed the 33-A loader.

About the time Hamilton took up the loading problem, E. C. Morgan applied for patents on a machine for simultaneously cutting, dislodging and loading coal. Jeffrey took over development of the basic idea in 1913, in which year the first machine (34-B) was installed at the Bailey-Wood mine in West Virginia. This equipment, however, never came into general use, although several installations, primarily for entry driving, were made. Early in the present century the Myers-Whaley loader with shovel-type loading head also was developed. After several years of experiments, a model was placed in the Wind Rock (Tenn.) mine, Wind Rock Coal & Coke Co., to prove the shovel motion. Then a complete machine was installed in 1908 at Wind Rock, where, due to inability to regulate car supply, it averaged only 60 to 70 tons per day. A second machine, for 5-ft. coal, was installed in 1910 at the Holden (W. Va.) mine, United States Coal & Oil Co., where it averaged 128 tons per day during a 6-day test run.

Conveyor Mining Grows

From 1910 to 1920, bituminous progress was marked by a slow growth of conveyor mining; the beginning of mechanization experiments in 1913 at the Mt. Gay (W. Va.) mine, Gay Coal & Coke Co., opened in 1904 by H. S. Gay, Sr., converted to longwall in 1905 and until lately the only operation regularly using mobile loaders on a long face; adoption of the Evans scraper, developed in the anthracite region, by the Pennsylvania Coal & Coke Corporation, central Pennsylvania, in 1917; installation of a Thew electric shovel in a thick-seam mine, Union Pacific Coal Co., Hanna, Wyo., in 1916; trial of mechanical loaders by two Utah companies—Independent Coal & Coke Co. (Myers-Whaley) and the United States Fuel Co. (Halby)—in 1917; installation of the Goodman scraper loader, Carrolltown Coal Co., St. Benedict, Pa., in 1918; and development of more than fifteen new mobile loaders, including the Jeffrey and Coloder types.

In 1916, an experimental-type Joy loader, developed by J. F. Joy, was installed in the Somers No. 2 mine, Pittsburgh Coal Co., to be succeeded in 1917 by the first successful type. With gathering arms driven by crank disks to pull the coal onto a central conveyor, Joy machines since have been produced in a variety of sizes and capacities, of which the most recent are the high-capacity 10 and 11BU types for thick coal, and the Joy, Jr., for thin seams. Climaxing the work of C. S. Oldroyd, an Oldroyd loader with revolving-bar digging unit was installed by the Pittsburgh & Erie Coal Co., Brownsville, Pa., in 1919.

But while loader types multiplied and installations, many experimental, were made throughout the East, Middle West and Rocky Mountain regions, annual tonnage loaded was small until shortly before 1920, as the bituminous industry was accustomed to seeing the annual output roughly double every ten years and had not yet begun to feel the double pinch of excess producing capacity and high wages. The influence of wage rates on mechanization is exemplified in Illinois, Indiana and the Rocky Mountain regions, which early adopted mechanical loading to reduce costs and thus maintain their competitive position, usually against hand-loading fields with lower scales. Still further evidence of the wage influence is furnished by rapid increase in mechanization in the Eastern and Southern fields following the upward readjustment of rates beginning with the bituminous code. And along with maintaining internal competitive relationships has come the industry-wide problem of keeping down cost to combat substitutes, another major factor in late mechanization progress.

The year 1920 ushered in the first wage agreement covering mechanical loading (Myers-Whaley shovels) at the Petersburg (Ind.) mine, Pike County Coal Corporation. In the same year (1920), the Southern Coal Coke & Mining Co., Belleville, Ill., installed a McKinlay entry driver equipped with two circular revolving cutter heads and supplemental cutting and wedging equipment. Later installations include the Union Colliery Co., Dowell, Ill., 1926, and the Chicago, Wilmington & Franklin Coal Co., New Orient, 1927, and others. Also, in 1922, the Montevallo Coal Mining Co., Aldrich, Ala., which had adopted chain-and-flight conveyors in 1916 as an adjunct to the longwall system instituted in 1906, installed the first shaker conveyors (the British Mavor & Coulson) in the United States.

In 1922, N. H. McClevy, Pike County Coal Corporation, started developing what eventually became the "Ace" high-capacity (approximately 6 tons) scraper loader, used on a long face in the company's mine. Three years or so later, Wyoming operators adopted the large scraper loaders, a leader in the movement being the Union Pacific Coal Co. with 125-hp. Goodman and Vulcan units moving 3½ tons.

The first 100-per-cent mobile-loader mine, Ayrshire Coal Co., Oakland City, Ind., using Joy equipment, was opened in 1922 by David Ingle, who, with his associates, was the first to double-shift loading machines in 1925. By 1923, the Pocahontas Fuel Co. had raised its mechanically loaded output to 998,000 tons.

The first central Pennsylvania mechanical-loading scale was adopted in 1923, and late that year the V-system of mining with Movor conveyors was inaugurated at the Norton (W. Va.) mine, West Virginia Coal & Coke Co. This system, by Glenn B. Southward, then chief engineer for the company, was the forerunner of others in later years, including in 1924 the Rachel (W. Va.) mine, Bertha Consumers Co., special Fairmont conveying equipment, and the Boncarbo (Colo.) operation, American Smelting & Refining Co., tracks, and in 1925 the Black Diamond Collieries Co., Coal Creek, Tenn., scrapers.

Scow System Developed

Development of still another conveyor featured 1923, when H. Denman and R. G. Johnson, Paris, Ark., with Clarence Claghorn, designed a low-type carrying unit (later manufactured by the United Iron Works Co.) for use on long faces in the Paris field. In this field also, George Colville, Jewell Coal Co., about 1925, developed the scow system in which the coal on a long face is broken down in large blocks, which drop on steel plates, or scows, operated by double-drum hoists. The blocks are pulled out to the roadway, where they are loaded on special cars.

Conveyor transportation in mobile-loader mines was proposed by Walter M. Dake in 1924, although there were no bituminous installations until 1935. In the former year, however, Jeffrey equipment for continuous loading and conveying systems was offered, including: the 43-A "Shortwaloader," a cutting and loading machine combining a shortwall cutter with the Hamilton loading principle; the 44-A sectional face conveyor-loader, designed to be jacked section by section into the broken-down coal; and the 47-A sectional conveyor for transporting the coal to a trip of cars on the entry.

The Goodman power shovel, first installed by the Union Colliery Co.,

Dowell, Ill., was another 1924 development. In the same year, the Pennsylvania Coal & Coke Corporation began using belt-type main and face conveyors in central Pennsylvania. Another central Pennsylvania development (1925) was the Lorain (Suppes) belt face and chain-and-flight main conveyors developed by R. A. Suppes, general superintendent, Knickerbocker mines, Johnstown, Pa.

Up to 1926, shaker conveyors still were hand-loaded. But in that year, equipment for converting them to self-loading units was developed at the Union Pacific Coal Co. mines, Wyoming. In that State, grades in many cases make conveying equipment the only practicable units, and, as the coal normally is brought downhill, shakers logically were indicated. Making this equipment self-loading would increase crew productivity, and these considerations led to the development of the "duckbill" loading head, which uses the reciprocating motion of the conveyor to load the coal.

By 1926, the output of self-loading equipment (excluding hand-loaded conveyors and similar equipment requiring hand shoveling) had increased to 10,022,195 net tons, although still only 1.8 per cent of the total bituminous output. The 1926 output, however, was five times the 1923 production of 1,879,726 tons, so it could be said that mechanization of loading was well on its way. By 1934, total output of all types of equipment, including hand-loaded conveyors, was 41,432,735 tons, or 12.2 per cent of the bituminous production.

Reflecting the rapid progress in mechanization in those States, the tonnage loaded mechanically in Wyoming was 84.1 per cent in 1934, and in Montana, 79.1 per cent. Wyoming also headed the percentage column in 1923, the earliest data year, with 8.8 per cent produced mechanically. Indiana, with 61.4 per cent in 1934, showed 4.8 per cent in 1923, against 1.9 per cent in Illinois, which reported 52.6 per cent in 1934.

In spite of progress, the first statewide mechanical-loading agreements were not adopted until 1928, in which year Illinois and Indiana contracts were signed. In this same year, large-scale pit-car loader application started in these States, later spreading to other fields. In many cases, particularly in Illinois and Indiana, pit-car loader use was but the intermediate state in the transition from hand to mobile loaders. Pit-car-loader tonnage still is, however, a substantial item in the mechanically loaded total.

Increasing interest in mechanization in the Eastern fields, which had been relatively slow to adopt the machine, was reflected in 1929 in the reopening of the Fairpoint (Ohio) No. 9 mine, acquired shortly before by the Hanna Coal Co., as a laboratory for developing mechanization methods for other company properties. Operations at Fairpoint started with duckbills on shaker conveyors in entries, and in 1930 the mine was converted to Whaley "Automat" loaders, first for entry driving and then throughout, followed by successive adoption of single, double and triple shifting. The continuing development of loaders was reflected in the Jeffrey 44-C machine in 1929, the forerunner of other similar units, and in the installation of the first Clarkson loader at Orient No. 1 mine, Chicago, Wilmington & Franklin Coal Co., Illinois, also in 1929.

Up to 1929, except for the Gay mine, standard room-and-pillar systems were almost exclusively employed with mobile loaders. Generally, pillars, particularly in the Middle West, where this custom prevailed even in hand-loading days, were not recovered. Many mines, however, had adopted mining plans permitting connection of tracks between rooms or the establishment of pick-up roads taking in several rooms to facilitate car-changing and gathering-locomotive operation. In 1929, the Standard Coal Co., Wheatland, Ind., introduced the "checkerboard" system, in which the length of the pillars was reduced by making more crosscuts, which were driven from both sides, thus permitting the coal to be loaded without laying switches and also allowing trips to be spotted on the room track for loading.

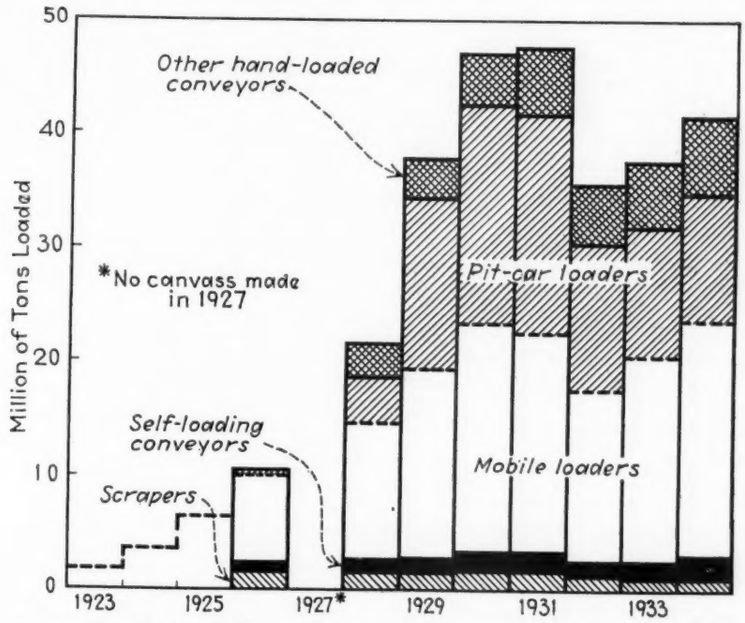


Fig. 3—Mechanical-loading progress in the bituminous industry in eleven years

Per-Shift Output Rises

In addition to several new mobile machines, including the Goodman, first installed by the Indiana & Illinois Coal Corporation, in Illinois, and adopted by the Linton-Summit Coal Co., Linton, Ind., for its 100-per-cent mechanized operation — New Hope—in 1933; the Joy 10BU, 11BU and Joy, Jr., 1935 and 1936; and the Jeffrey L-400 and "Umeco," 1936, the period from 1930 to the present has been marked by a rapid rise in per-shift output of mobile loaders to 500 to 600 tons or more in many cases, as compared to 125 to 150 tons around 1911; the recent adoption of conveyor transportation at mobile-loader mines; and a rapid increase in the use of mother conveyors at conveyor operations.

With, and in part responsible for, the increased output of the newer high-capacity mobile loaders, has come larger (5- or 6-ton) pit cars and the use of two changing locomotives per machine to cut down changing time. Greater acceptance of the idea that tons per man-shift

rather than per machine-shift is the test of mechanical loading efficiency is in part responsible for the widening use of small lower-capacity loaders in mines where larger equipment is not suitable. Measuring mechanical-loader progress in output per man-shift, 20 tons or more for all men employed underground at a mine is not uncommon at present.

Although suggested in 1924, it was not until 1935 that transporting coal from mobile loaders at the face to the tipple by conveyors was actually put in practice—at the Hueysville (Ky.) mine, Goose Creek Mining Co., where the coal is loaded by Joy, Jr., loading machines into Joy chain-and-flight conveyors, which in turn discharge onto a Joy-M. & C. belt conveyor carrying the coal to the tipple. While conveyor transportation previously had been employed to carry coal out to a pit car on the entry, and although complete conveyor transportation systems had been installed at at least one other mine—in the anthracite region—Goose Creek represents the first of its type of equipment combination—mobile loaders to conveyors to the surface. Second is the Porter Coal Co., Adamsville, Ala., 8BU loaders, and third is the Detroit Mining Co., Gordon, W. Va., Joy, Jrs., both early in 1936.

Loaders on Long Faces

This year, the New Castle Coal Co., New Castle, Ala., and the E. J. Jones mine, near Zanesville, Ohio, started using mobile loaders on a long face, joining the Gay mine, West Virginia, which adopted the principle in 1913, and the Clinton (Ind.) mine, J. K. Dering Coal Co., employing Shortwaloaders on long faces prior to 1930. In the earlier operations, the coal is or was loaded into pit cars, whereas in the 1936 operations conveyors take the coal away from Joy loaders.

While not strictly long-face operation, the St. Ellen mine, southern Illinois, for some years has laid track across the face to permit loading the small cars then employed in trips to reduce the changing time. "Circle haulage," in which tracks come in one opening, cross the face and go out another, was installed at the No. 10 mine, Binkley Mining Co., Universal, Ind., by F. M. Schull in 1933, for much the same purpose. At No. 10, however, rooms are started in groups of ten which are cut together into five groups of two each after the first crosscut, then into two groups of four each with a center group of two after about the third crosscut, and finally, in the last 50 ft. or so of advance, into one long face ten rooms wide.

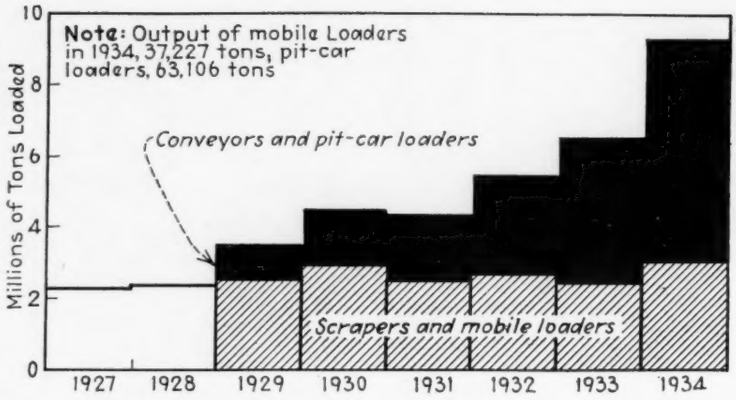


Fig. 4—Mechanically loaded tonnage increases over four times in eight years in the anthracite region

Although conveyors were first applied to long faces, which long have been the major province of this equipment, they were soon adapted to room-and-pillar mining. Usually, in the older days, each room unit discharged into pit cars on the entry. Beginning about 1930, however, following earlier use of long belts by the Stonega Coke & Coal Co., Virginia, mother conveyors of the belt or chain-and-flight types receiving coal from a number of room units began to spread at bituminous mines.

Use of the belt-type mother conveyor is exemplified in central Pennsylvania by the No. 15 mine installation, Barnes Coal Co., started in 1931. In this installation, rooms are turned both ways from the entry, in which a Jeffrey belt conveyor is located. Four chain-and-flight conveyor units, each consisting of a 61-AM room conveyor with 61-HG face conveyor, are installed in rooms, two in a pair of rooms on one side of the entry and two in a pair on the opposite side. Using these conveyors, rooms are driven and the pillars drawn on the retreat out of the entry. Three room-conveyor units on each side are used in the 1934 installation of the Jewell Ridge (Va.) Coal Corporation.

In the other general class of mother-conveyor installations, a chain-and-flight conveyor receives the coal from the room units and conducts it to a central loading point on the room entry, as distinguished from transporting it to the mouth of the room entry where the belt is used. In most cases, four rooms are driven at a time, as in the Submarine No. 2 installation, Ferguson Coal Co., Clinton, Ind., in 1931. Pillars, however, are not recovered at Submarine, while in the Affinity (W. Va.) installation, Pemberton Coal & Coke Co., made in 1935 and also based on working four places at a time, pillars are robbed back as soon as the rooms are completed. Jeffrey chain-and-flight face and room conveyors discharge into a chain-and-flight mother conveyor laid alongside the track in the heading.

In the above installations, rooms in most cases are driven approximately the customary width. In late years, however, room width has been increased to 70, 80 or 90 ft., leaving a narrow pillar, at a number of operations to increase the output of a single place.

In the anthracite region, mechanization progress has largely revolved around scrapers and conveyors, as natural conditions make mobile-loader installations difficult or undesirable in most cases, although some are used for loading coal and a larger number in driving gangways and tunnels in rock or coal. In addition to thin-seam mining, where they permit extraction without costly lifting of bottom, scrapers and conveyors are widely used in pillar recovery in second, third or fourth mining, where they avoid expensive openings to accommodate cars. Shakers predominate in conveyor installations, although chain-and-flight units have become more popular in late years. The anthracite region also employs the elevating conveyor to reach small basins below the normal working level.

Although there may have been previous conveyor installations, mechanization in the anthracite region apparently got its start around 1912. At that time, David Lloyd, then superintendent, installed the first Jeffrey underground conveyors on long faces in the Dodge mine, Glen Alden Coal Co., in the Northern field. This field still leads in anthracite mechanization because of the preponderance of comparatively light

pitches favoring installation of machines. Four 250-ft. Link-Belt longwall conveyors were installed by the Pennsylvania Coal Co. and the Hillside Coal & Iron Co. in 1914.

Probably the first United States scraper-loader installations, at the Seneca and Maltby collieries, Lehigh Valley Coal Co., Wilkes-Barre, Pa., were another 1914 development. Adopted by George P. Gallagher, then assistant superintendent, Lackawanna division, to recover thin coal, using the chamber-and-pillar system, the scrapers were first pulled back and forth by a mule. Later, a winch on a locomotive was employed to handle the units, presaging the later use of the double-drum hoist. Cars were set on short spur tracks at the mouths of the chambers.

In 1916, the year in which the first pit-car loader (Jeffrey) was installed by the Hudson Coal Co., Cadwallader Evans, now general manager, started experiments with scrapers for mining the "Twenty-Inch" bed. After building several, a patent was obtained on a scraper that would of itself dig out and remove undercut coal. By 1918, 35 were in use and 60 under construction. Twelve also were being employed by the Pennsylvania Coal & Coke Corporation, which had 35 under construction.

By 1928, the Hudson Coal Co. was producing 909,000 tons, approximately 14.4 per cent of its output, with scrapers, mostly on long faces in thin coal. In 1920 or 1921, C. H. Strange, superintendent, Pine Hill Coal Co., Minersville, offered a scraper with a hinged rear gate which was pulled down as the scraper moved into the coal and was raised by the head rope when it moved out.

The shaker conveyor, since widely used, was introduced in 1925 by A. B. Jessup, vice-president, Jeddo-Highland Coal Co., Jeddo, Pa. Active installation soon began, equipment including, in addition to units developed at the mines, the Eickhoff, Siemens-Schukertwerke, Flory, Vulcan (1927) and, in succeeding years, the Lee, La-del, Goodman (1931), Schmidt-Kranz and others. Anthracite shakers usually are hand-loaded, although a few self-loading heads are employed.

By 1927, mechanical-loading equipment accounted for an output of 2,223,000 net tons, or 2.8 per cent of the total by all methods. In 1934, mechanically produced output was 9,284,000 tons (over 80 per cent from the Northern field), or 16.2 per cent of the total.

Although the general anthracite practice is to operate conveyors in individual places, several mother-belt installations have been made in the Northern field, which includes one completely conveyor mine. Meco mother belts taking coal from shaker conveyors were adopted by the Pittston Co. in 1929 in a general mechanization program involving mother belts; shaker, belt, chain-and-flight and mat-face room conveyors; Sullivan scrapers and other equipment. The Pittston Co. also was one of the earliest major users of small 7½-hp. scraper units operated by crews of three or four men, against six or seven for the 25-hp. scraper previously employed at most anthracite operations.

In 1933, the Penn Anthracite Mining Co. opened the Harry Taylor mine, Scranton, with Jeffrey equipment, probably the first United States all-conveyor mine. At this operation, chain-and-flight units discharge onto a belt system which conveys the coal up to the slope opening and down the mountainside to the railroad car. In this same year, chain-and-flight elevating conveyors (Wilmot, Jeffrey, etc.) began to make headway in the Middle and Southern fields for recovering small basins or other local areas below the normal working level. Receiving coal from buggies or tributary conveyor systems, the elevating conveyor eliminates the hoist and larger and more costly pit-car slope and track otherwise required in working such areas.

In 1934, the Lehigh Navigation Coal Co. installed at its Coaldale No. 9 colliery a Joy 8BU loader, which dumps its coal into Vulcan shakers for transportation to the gangway loading station, one of the first examples of conveyors serving mobile loaders.

Special shaker-conveyor units for driving gangways were another 1934 development. The Hudson Coal Co., one of the first, has, starting in 1933, installed a number of Vulcan "gangway loaders," consisting of a shaker conveyor, for installation at the side of an opening, with an inclined rear section to bring the discharge end up to pit-car height. To facilitate shaking the coal up the inclined section, a Westinghouse control for altering the motor speed on each stroke is included. Hudson also adopted in 1934 a number of Eickhoff "Uplift" shakers. Pivoted legs, with a spring puller in the drive, make it possible to lift the coal up an 8½-deg. rise to the pit car.

+ MILESTONES IN MECHANICAL LOADING +

TABULATED BELOW are the major steps in the progress of mechanization of loading, as far as could be ascertained, from the time the first Stanley header was installed in Colorado until the present day. Loading, entry-driving, conveying and scraping equipment only is included in the tabulation. Advances in the mechanization of other activities besides loading are reviewed elsewhere in this issue.

1888—Stanley header, imported from England
Franceville mine, Colorado Springs, Colo.

1890—Stanley header with conveyor
Bennett mine, Lebanon, Ill.

1893—Experimental work leading to the development of the Jones (Coloder) loading machine begins

1896—O'Toole mining and loading machine
Leisenring No. 3, H. C. Frick Coke Co.

1902—Conveyors first installed on longwall faces by Clarence R. Claghorn
Vinton Collieries Co., Vintondale, Pa.

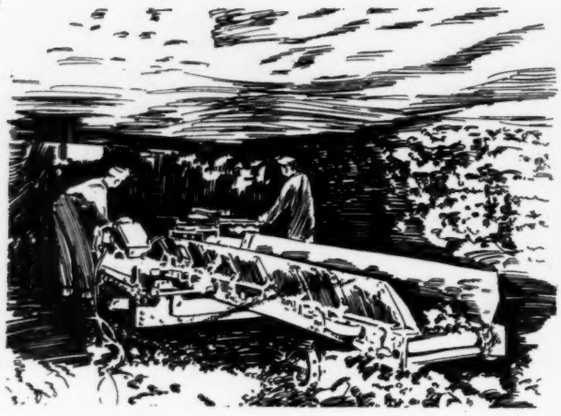
1903—Hamilton loader
St. Louis & Big Muddy Coal Co., Dewmaine, Ill.

1908—Myers-Whaley loader
Windrock Coal & Coke Co., Windrock, Tenn.

1910—Hammond loader
Filbert mine, H. C. Frick Coke Co.

1911—Ingersoll-Rand heading machine (cutter and loader)
Four States Coal & Coke Co., Annabelle, W. Va.

1911—Jackson loader
Tried at Bridgeport mine, H. C. Frick Coke Co.



1911—Jeffrey 32-A loader
McKell Coal & Coke Co., Kilsyth, W. Va.

1912—First chain conveyor in anthracite (Jeffrey)
Glen Alden Coal Co., Dodge mine, Scranton, Pa.

1913—Gay Coal & Coke Co. starts mechanization experiments
Mt. Gay, W. Va.

1913—Jeffrey 34-B entry driver
Bailey-Wood Coal Co., West Virginia.

1914—First scraper loaders
Seneca and Maltby, Lehigh Valley Coal Co., Wilkes-Barre, Pa.

1914—Link-Belt long-face conveyors
Pennsylvania Coal Co., Hillside Coal and Iron Co. (anthracite)

1914—Halby loading machine
Consolidation Coal Co., Jenkins, Ky.

1914—Powell mining and loading machine
Tried at Ronco: H. C. Frick Coke Co.

1914—Jeffrey shortwall loader (37-A)
Pittsburgh Coal Co., Willock, Pa.

1915—Westmoreland loader
Hannastown, Pa.

1915—Kuhn loader
Somers No. 2 mine, Pittsburgh Coal Co.

1915—Billings loader
Under test, Vestaburg, Pa.; Vesta Coal Co.

1916—Evans scraper loader (a)
Hudson Coal Co., Scranton, Pa.

1916—Thew electric shovels installed underground
Union Pacific Coal Co., Hanna, Wyo.

1916—First Jeffrey pit-car loader
Hudson Coal Co., Scranton, Pa.

1916—Experimental Joy-type loader
Pittsburgh Coal Co., Somers No. 2, Pricedale, Pa.

1916—Chain-and-flight conveyors
Montevallo Coal Mining Co., Aldrich, Ala.

1917—Halby and Myers-Whaley loaders installed in Utah
Independent Coal & Coke Co.; U. S. Fuel Co.

1917—First successful Joy loader (b)
Somers No. 2, Pittsburgh Coal Co.

1917—Experimental mining and loading machine (Jeffrey 39-A)
Somers No. 2, Pittsburgh Coal Co.

1917—Evans scrapers
Pennsylvania Coal & Coke Co., central Penna.

1918—Installation of modern Coloders begins
Pocahontas Fuel Co., West Virginia

1918—Goodman 23-B scraper loader (c)
Carrolltown Coal Co., St. Benedict, Pa.

1919—Jeffrey entry driver, Illinois
Valier Coal Co.

1919—Oldroyd loader
Pittsburgh & Erie Coal Co., Brownsville, Pa.

1919—Dillig tractor loader
B. S. Hammill Coal Co., Scotts Run, Pa.

1920—McKinlay entry driver
Southern Coal, Coke & Mining Co., Belleville, Ill.

1920—Joy loaders, Myers-Whaley shovels, Illinois
Chicago, Wilmington & Franklin Coal Co., New Orient

1920—Crawford-London loader
Tried at Lochvale, Pa.; Superior Coal Co.

1920—Hunt loader
Elkhorn Piney Coal Mining Co., Weeksbury, Ky.

1920—Strange scraper, with hinged rear gate
Pine Hill Coal Co., Minersville, Pa.

1920—O'Toole heading driver
U. S. Coal & Coke Co., Gary, W. Va.

1920—First loading-machine wage scale (Myers-Whaley shovels)
Pike County Coal Corporation, Petersburg, Ind.

1921—American shortwall loader
Buffalo Eagle Collieries Co., Braeholm, W. Va.

1921—Brown electric shovel
Locust Mountain Coal Co., Shenandoah, Pa.

1921—"Portable" pit-car loader

1921—Loading machines in Colorado (Myers-Whaley shovels)
Columbine Mine, Rocky Mountain Fuel Co.

1921—Corrigan shovel loader

1921—"Auto-Moto" loader
To be tried, New River Co., Mt. Hope, W. Va.

1922—Pioneer shaker conveyor installation (Mavor & Coulson)
Montevallo Coal Mining Co., Aldrich, Ala.

1922—Conway rock loader
Union Colliery Co., Dowell, Ill.

1922—Rock, in taking roof and bottom, handled by Myers-Whaley shovels
Hale Coal Co., Houtzdale, Pa.

1922—"Shuveloader" (rock)
Old Ben Coal Corporation, Illinois

1922—Peale loader
Peale, Peacock & Kerr, Inc., Bloomington, Pa.

1922—Development of "Ace" (6-ton) scraper starts
Pike County Coal Corporation, Petersburg, Ind.

1922—Wilson "Chainloader"
Southern Coal, Coke & Mining Co., Belleville, Ill.

1922—Buffom loader
Leckrone No. 1, H. C. Frick Coke Co.

1922—All-mechanical mine, Joy loaders
David Ingle, Ayrshire Coal Co., Oakland City, Ind.

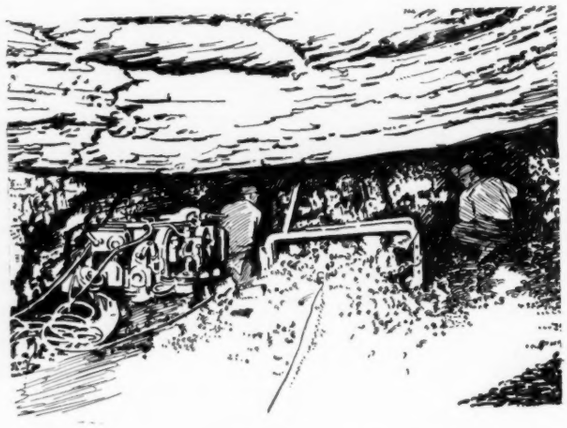
1922—Full-mechanical basis with Coloders
Pocahontas Fuel Co., Switchback, W. Pa.

1923—First mechanical-loading scale in Pennsylvania (Myers-Whaley rock shovels)
Peale, Peacock & Kerr, Inc.

1923—V-system with Movor conveyor starts
West Virginia Coal & Coke Co., Norton, W. Va.

1923—Holmested loader
Gay Coal & Coke Co., Mt. Gay, W. Va.

1923—998,000 tons with Coloders
Pocahontas Fuel Co., Virginia - West Virginia



(a) License to manufacture issued to various concerns, including Goodman Mfg. Co.

(b) Forerunner of 4BU, 5BU, 6BU, 7BU, 8BU, 10BU, 11BU and Joy, Jr., loaders

(c) Forerunner of a number of types and sizes by the Goodman Mfg. Co.

(d) Forerunner of a complete line of conveying equipment by the Fairmont Machinery Co.

(e) In addition to other types of conveying equipment offered by Gellatly & Co.

(f) Forerunner of additional types in the series (44-D, 44-CC, 44-DD, 44-E, 44-EE).

1923—Mason loader
Dearth mine, H. C. Frick Coke Co.

1923—Jeffrey 42-A longface machine
Francisco Mining Co., Francisco, Ind.

1923—O'Toole cutting and loading machine
U. S. Coal & Coke Co., Gary, W. Va.

1923—H. Denman and R. G. Johnson, with C. Claghorn, develop low-type carrying conveyor (United) for Paris (Ark.) field
Paris Purity Coal Co.

1924—Use of conveyor transportation in mobile-loader mines proposed by Walter M. Dake

1924—Goodman face drag
Leckrone No. 1, H. C. Frick Coke Co.

1924—V-system with special Fairmont conveyors (d)
Bertha Consumers Co., Rachel, W. Va

1924—First Illinois loading-machine contract
Chicago, Wilmington & Franklin Coal Co., New Orient

1924—Goodman power shovel
Union Colliery Co., Dowell, Ill.

1924—Ingersoll mining and loading machine
Lambert, H. C. Frick Coke Co.

1924—Jeffrey offers self-loading flexible longwall face conveyor (44-A), sectional chain conveyors (47-A) and "Shortwaloader" for complete loading and transportation systems on either long faces or in narrow places

1924—Stockly (American) loader
Leckrone, H. C. Frick Coke Co.

1924—Belt face and main conveyors installed
Pennsylvania Coal & Coke Co., central Penna.

1924—Hoar shovel adopted for loading rock in reopening old workings
Price-Pancoast Coal Co., Throop, Pa.

1925—Scow system developed in Arkansas
Jewell Coal Co., Paris, Ark.

1925—Large scrapers (Goodman 125-hp.) installed in Wyoming
Union Pacific Coal Co.

1925—Twenty Shortwaloaders shipped
J. K. Dering Coal Co., Illinois-Indiana

1925—Early Eickhoff shaker conveyors
Union Pacific Coal Co., Wyoming
Virginia Iron, Coal & Coke Co., Virginia

1925—Mullen conveying and loading machine
Leckrone No. 5, H. C. Frick Coke Co.

1925—McEachen loader
New England Fuel & Transportation Co., Lowesville, W. Va.

1925—Chicago pit-car loader
Indiana mines

1925—Lorain (Suppes) belt face and chain main conveyors
Knickerbocker mines, Johnstown, Pa.

1925—V-system with scrapers
Black Diamond Coll. Co., Coal Creek, Tenn.

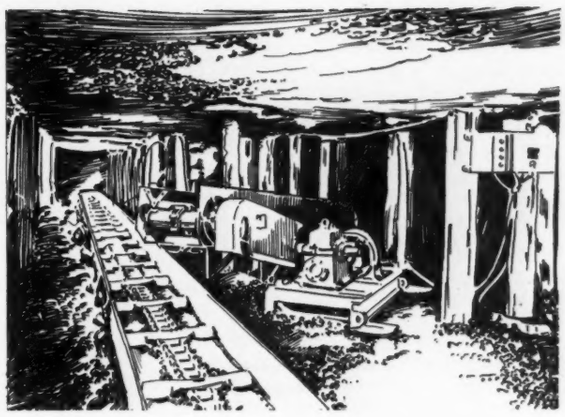
1925—Sullivan loader
United States Fuel Co., Danville, Ill.

1925—Riley loader

1925—Loading machines double-shifted
David Ingle, Ayrshire, Ind.

1925—Ironton swinging conveyor

1925—Shaking conveyors introduced in anthracite by A. B. Jessup
Jeddo-Highland Coal Co., Jeddo, Pa.



1925—Thorsten belt-face conveyor with elevating section
Allegheny-Pittsburgh Coal Co., Pennsylvania
Windsor Power House Coal Co., West Virginia

1926—Shaker conveyors (Eickhoff, Siemens-Schukertwerke, Flory, etc.) begin to make headway in hard-coal mines

1926—Vulcan (Denver) electric shakers
Stag Canon Branch, Phelps Dodge Corporation, Dawson, N. M.

1926—Duckbill self-loading head developed for shaker conveyors
Union Pacific Coal Co., Rock Springs, Wyo.

1926—Sullivan scraper (7½-hp.)
Glendale Anthracite Collieries, Scranton, Pa.

1926—Whammond loader
Allegheny River Mining Co., Kittanning, Pa.

1926—Whaley single-motion loader
Consolidation Coal Co., Jenkins, Ky.

1926—Schoew track-mounted belt conveyor for trip loading

1926—Heavy-duty (125-hp. 3½-ton) scrapers, Vulcan (Denver)
Union Pacific Coal Co., Rock Springs, Wyo.

1926—Shanaberger loader
Barnes & Tucker Co., central Pennsylvania

1927—Sullivan scraper (large)
Lehigh Valley Coal Co., Wilkes-Barre, Pa.

1927—Jones flexible shaker conveyor
Victor-American Fuel Co., Colorado

1927—First woven-wire mat-face conveyor (Gellatly) (e)
Garfield Smokeless Coal Co., Bolivar, Pa.

1927—Vulcan (Wilkes-Barre) shaker conveyors offered

1928—State-wide mechanical-loading agreements signed
Illinois and Indiana

1928—Covington loader
Carbon Fuel Co., Carbon, W. Va.

1928—Start of large-scale pit-car-loader development (General, Fairfield, Mancha, Duncan, Brownie, Northern, National, Jeffrey, Utility, Tracy, Mt. Vernon, Goodman, etc.)

1928—Large-scale pit-car-loader installation begins
Illinois and Indiana mines

1929—Lang pit-car loader
Arkwright Coal Co., Mona, W. Va.

1929—Vulcan self-loading head, swinging joints and swinging discharge chute for shaking conveyors

1929—Jones track-mounted movable room-belt conveyor unit
American Rolling Mill Co., Nellis, W. Va.

1929—Whaley "Automat" coal-loading machine

1929—Valley Camp pit-car loader and Paisley trip-loading belt
Valley Camp Coal Co. mines, W. Va.

1929—Mechanization of Fairpoint No. 9 laboratory mine starts with duckbills; Whaley Automat loaders adopted in 1930
Hanna Coal Co., Ohio

1929—Mother belts installed in general mechanization program involving Meco main and room belts and shakers, Pittston shakers and face belts, Gellatly room and mat-face conveyors, Sullivan scrapers, etc.
Pittston Co., Dunmore, Pa.

1929—Jeffrey 44-C loader (f)
Illinois and Indiana

1929—Checkerboard system for mobile loaders developed
Standard Coal Co., Wheatland, Ind.

1929—Clarkson loader
Orient No. 1, Chicago, Wilmington & Franklin Coal Co., Illinois

1930—Mining with Meco belt on 800-ft. face advanced 1,000 ft.
Stonega Coke & Coal Co., Derby, Va.

1930—Ironton 90-deg. turns for shaker conveyors offered

1930-32—Goodman acquires "Duckbill" loading head; takes over "Cosco" shakers

1931—Group conveyor plan adopted
Ferguson Coal Co., Clinton, Ind.

1931—Goodman shaker drives
Lehigh Valley Coal Co., Wilkes-Barre, Pa.

1931—Room panels worked with Jeffrey mother belts and late-type chain conveyors
Barnes Coal Co., Barnesboro, Pa.

1932—Schmidt-Kranz shaker drives
Anthracite

1933—Utility loading machine
Indiana

1933—Goodman track-mounted loader
Indiana & Illinois Coal Corporation, Illinois;
Linton-Summit Coal Co., Linton, Ind.

1933—First 100-per-cent conveyor mine, Jeffrey belt and chain conveyors and reversible shortwalls
Harry Taylor mine, Penn Anthracite Mining Co., Scranton, Pa.

1933—Elevating conveyors (Wilmot, Jeffrey, etc.) make headway
Middle and Southern fields, anthracite

1933—Vulcan "gangway" loader (shaker conveyor) with special electrical control
Hudson Coal Co., Scranton, Pa.

1934—Robins belt-conveying equipment
Lehigh Valley Coal Co., Wilkes-Barre, Pa.

1934—Shakers carry coal away from Joy loader
Coaldale No. 9, Lehigh Navigation Coal Co.

1934—Eickhoff "uplift" shaking conveyor
Anthracite

1934—Goodman reversible shaker conveyor

1935—First 100-per-cent mine using Joy, Jr., loaders and conveyor transportation
Goose Creek Mining Co., Hueysville, Ky.

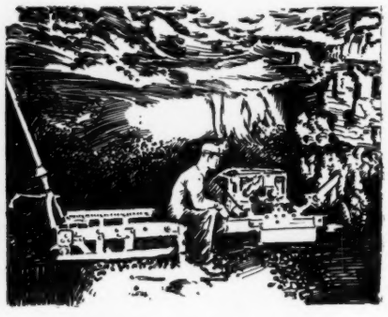
1936—"Umeco" loader
St. Louis & O'Fallon Coal Co., O'Fallon, Ill.

1936—Jeffrey L-400 loader

1936—Joy loaders on long faces with conveyor transportation
New Castle Coal Co., Alabama
E. J. Jones, Ohio

Hand—before 1877

Puncher—1877



Breast Machine—1877

Early Undercutting Methods and Equipment and Dates of First Use

FACE PREPARATION

BREAKING down the coal and preparing it for loading, commonly known as face preparation, has, like many other activities, been increasingly mechanized in the bituminous industry in the past 25 years. In 1911, when no method was specified for 9.4 per cent of the tonnage reported to the U. S. Geological Survey, 29.7 per cent of the United States output was mined by hand, 17 per cent was shot off the solid and 43.9 per cent was mined with cutting machines of various types. In 1891, the first year for which data covering cutting-machine use were collected, 5.3 per cent of the soft-coal output was cut by machines.

By 1934, when the unspecified tonnage reported to the U. S. Bureau of Mines totaled only 0.1 per cent and 5.8 per cent was produced by stripping, the total output cut by machines had risen to 79.2 per cent, whereas hand mining accounted for 10.1 per cent and shooting off the solid for 4.8 per cent. On the basis of underground output alone, excluding strip coal, the per cent cut by machines was 84.1 in 1934. A total of 11,905 cutting machines were in use in 1934, against 545 in 1891. The peak in number of machines used, however, was reached with 21,229 in 1923, in which year they accounted for a total of 377,435,543 tons, against 284,676,715 tons in 1934.

Anthracite, because of the nature of the mining problem, presents a radically different picture. Steep pitches in most instances make the use of cutting equipment difficult, if not undesirable, although 169 machines were in use in 1934, largely in connection with mechanical loading on light pitches. These machines cut 1,981,088 tons, or 3.5 per cent of the fresh-mined output in 1934, against 69,907 tons, or 0.07 per cent, in 1911. Late years, however, have brought considerable thought to bear on the question of cutting on pitches, and in one case, at the Salem Hill colliery, the Haddock Mining Co., cutting has been done up a 39-deg. pitch on a long face, with a possibility of eventual use of the machine on a 44-deg. pitch.

While the increase in machine-cut coal and the rise of the shortwall cutter have been the major developments in underground face preparation in the bituminous industry since 1911, when *Coal Age* first appeared, progress since that time also has included development of track-mounted cutters and their extensive use in cutting out impurity bands; increased use of power-driven drilling equipment and the design of both track-mounted and one-man portable units; a substantial rise in the use of permissible powder (11,300 lb. was sold in 1902, 13,428,239 lb. in 1911, and 38,665,149 lb. in 1935); greater use of cushioned blasting and snubbing, the latter particularly with mobile loaders; de-

velopment of "shooting" with inert gas or compressed air; rising interest in shearing supplemented by the development of shearing and combination cutting-and-shearing machines; and the use in late years of special types of cutter bits, hard-surfacing and heat-treating.

Although explosives were known much earlier, apparently their first use to aid the miner was in the Royal mines, Schemnitz, Hungary, in 1627. The first record of blasting in American coal mines goes back to 1818, when John Flannigan, a rock quarryman, was sent from Milford, Conn., to Plymouth, Pa., to shoot coal in the Smith Bros. mine. While powder greatly reduced the labor of the miner and consequently increased his output, shooting off the solid, particularly in bituminous mines, had several disadvantages; i.e., increased charge required, with consequent greater shattering effect and reduction in coarse-coal output—in earlier days the major product, as slack in many fields was unmarketable—and a heavier burden on the explosive charge, thus increasing the possibility of blown-out or windy shots. Consequently, undercutting was early adopted to provide an additional free face, and, lacking machinery, the miner was forced to use his pick for this purpose—an arduous and time-consuming task.

Problem Attacked Early

Inventors early attacked the problem of developing a mechanical coal cutter, and probably the earliest patent was issued to Michael Menzies, an Englishman, in 1761. In common with most designers in that day, Menzies attempted to imitate the action of the miner with his pick, and proposed to drive his pick by reach rods from the surface. Numerous patents were taken out in succeeding years, and in 1858 Chamberlain offered a handwheel set with chisel bits, followed by the rotary drill battery, Boyd and Greer, 1867; hydraulic cylinder with extended piston carrying cutter bits, Bunning and Cochran, 1867; revolving-wheel cutter powered by compressed air, one of the first to meet any degree of commercial success, Walker, 1868; chain-type cutter, Hurd, 1869; and the horn-type cutter bar, Lucas and Nichols, 1873.

In the United States, the Harrison puncher was offered in 1877 and in the same year a Jeffrey (Lechner) revolving-bar breast machine was installed by the Straitsville Central Mining Co., New Straitsville, Ohio. Prior to 1888, 735 machines were sold by American manufacturers, many of which doubtless were soon discarded. The revolving bar of the original breast machine, which was not self-propelling and would not remove the cuttings from the kerf, was set with chisel bits. The puncher machine, in essence, represented the application of the hammer-drill action to coal cutting. Earlier types generally operated off an inclined puncher board and cut in the bottom, as it was not until about 1905 that post-mounted types, such as the Ingersoll-Rand "Radial-axe," permitting a cut to be made at points up on the face, were developed.

Except for a few longwall cutters, punchers and breast machines held the stage until about 1910, when the shortwall cutter, and later track-mounted machines, came in and practically took over the field in about ten years. The first experiments with electric drives for cutting machines took place in 1885. Lechner began experiments with the cutter chain before 1887 and continued them after leaving the Jeffrey organization in that year. Development of the first chain-type cutting machines, however, is credited to Elmer A. Sperry, who later invented the gyroscope. A number of longwall machines were built by the Sperry Electric Mining Machine Co., starting in 1888, for installation in the Lexington field of Missouri.

In 1893, a Sullivan air-operated horn-type longwall cutter with a cleaning chain paralleling the horn was shipped to Nova Scotia. By 1894, principles for practically all later breast-machine installations had been established, and in that year an advanced-type Jeffrey chain machine was installed in the Congo mine, in Ohio. In that same year, a Sullivan chain-type longwall cutter with "baby buggy" to hold it to the face was installed in Nova Scotia, followed in 1895 by a similar machine with a chain feed. The first Goodman breast machine was installed by the Rostraver Coal Co., Monongahela City, Pa., in 1897, and in the same year a Sullivan air-operated chain-type "room-and-pillar" cutter with chain feed was shipped to Moon Run, Pa., followed by an electric machine in 1898. The first CE machine was shipped to Vintondale, Pa., in 1899.

Shortwalls Introduced

Introduction of the Jeffrey shortwall cutter with rope feed was a feature of the year 1906. The first Goodman shortwall cutter with rope feed was installed by the Carrolltown Coal Co., St. Benedict, Pa., in 1911. By 1910, shortwall cutters in use, as reported to the U. S. Geological Survey, were 47. From that year on, the advance of the shortwall was rapid.

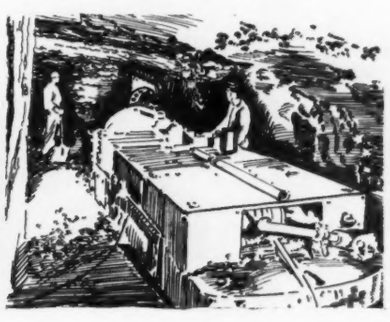
Power-driven drilling equipment lagged but little behind power-driven cutting equipment, and electrically operated coal augers began to make their appearance in numbers about 1911, including types, such as the Fairmont, designed for mounting on cutting machines. One-man portable drills, such as the Chicago Pneumatic, Cincinnati and Spry, were offered in 1917-18 and 1920. The Jeffrey track-mounted drilling machine with single spindle came out about 1918, and was the predecessor of double-spindle drilling machines employed in the Elkhorn (Ky.) mines of the Consolidation Coal Co. in 1927. Detachable bits for coal

Modern cutting machines and dates when they or their predecessors were first used

Shortwall—1897

Track-mounted—1911

Universal—1916



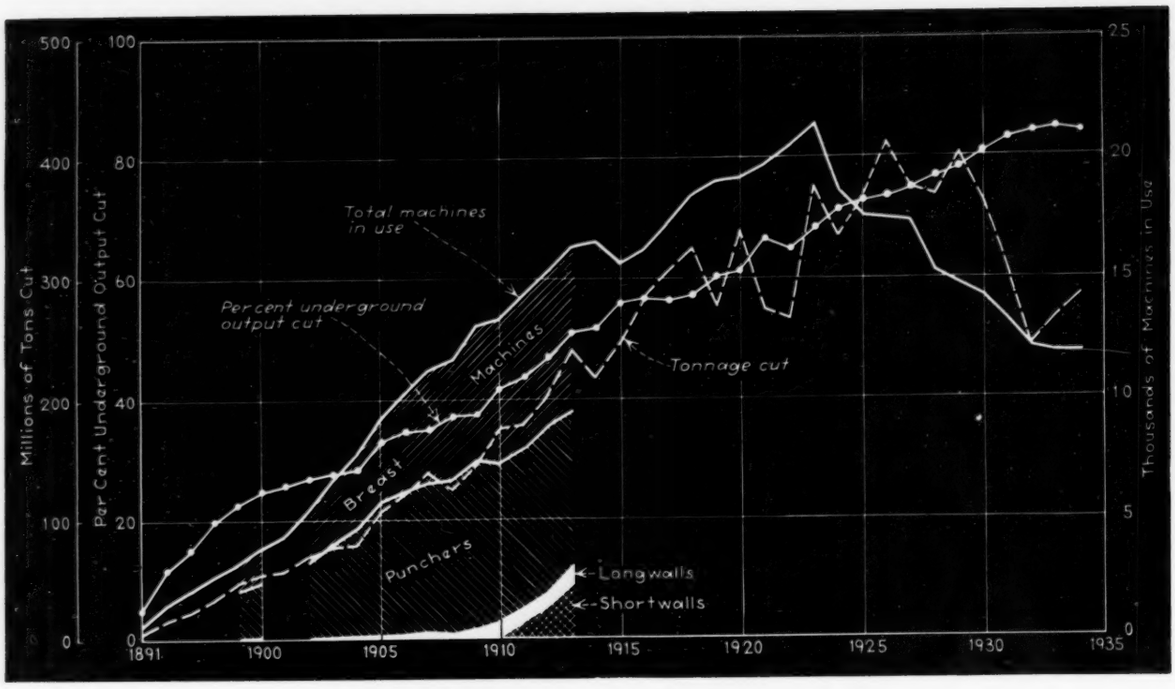


Fig. 1—Mining-machine growth from 1891 to the present day

augers also were a comparatively early development, including the Howells bit, 1920; Chismer pick bit, 1922; and the Barker "Gold Edge" bit, about 1926.

Alternating current for mining machines was tested at the Rugby (Colo.) operation, Star Mining Co., in 1912, using a Sullivan cutter. About 1914, Morgan-Gardner offered a cutter bar for making 3¼-in. kerf. The narrow-kerf question, offering the possibility of a substantial decrease in cuttings, has been revived only lately, but in 1914 or 1915, the Wasson Coal Co., Saline County, Illinois, installed a number of narrow-kerf machines. First U. S. Bureau of Mines approvals as permissible (100 and 100A) were granted on a cutting machine—Sullivan CE-7—on Oct. 20, 1914, although the first totally inclosed cutting-machine motor was developed in 1903. In 1934, approved-type cutters numbered 5,218 out of a total of 11,905. In 1920, a Goodman shortwall cutter with two power-driven feed drums providing high and low speeds was installed by the Lindley Coal Co., Houston, Pa.

Although the shortwall machine was coming in and the track-mounted type was just around the corner, interest in other types still was active in 1911. New units developed in that year included the Hoadley-Knight cutter, a combination cutting, crushing and water-conveying machine said to have been used in the Lewisburg mine in Alabama in 1912, and the Hess dustless cutter with a horn-type bar that both revolved and reciprocated back and forth, built in the shops of the Gauley Mountain Coal Co., Ansted, W. Va. Hirst disk cutters were another machine in use in 1911, and in 1922 H. T. and R. E. Booker developed a modification of the puncher employing a cutting disk instead of the pick point and installed it in the Eureka No. 35 mine, Berwind-White Coal Mining Co., Windber, Pa.

The period 1911-15 was marked by several important departures from previous cutting-machine design and practice. The Jeffrey track-mounted top cutter, developed starting in 1908 at the Gary (W. Va.) mines of the United States Coal & Coke Co., at the instance of Col. Edward O'Toole, was offered in 1911. The continuous-type cutters previously developed had reduced the time and labor required in moving the older punchers and breast machines along the face and now the top cutter made several new objectives possible, including: cutting in impurity layers over the coal and protection of tender roof by leaving up top coal and/or transferring the shock of blasting to the bottom. Also, the time required for making the machine ready for cutting and getting out of the place was substantially reduced.

A short time later, still another objective was made possible by the Jeffrey track-mounted turret-type cutter, developed, at the instance of Everett Drennen, to cut out a shale parting in the Elkhorn (Ky.) mines of the Consolidation Coal Co. The machine was made with a power-driven height adjustment for the cutter bar to permit cutting at various levels. In 1914, Main Island Creek Coal Co., Yuma, W. Va., installed the first Goodman "straight-face" top and center cutter designed to cut a straight, rather than curved, face. These machines and later types opened up a new field of face preparation by making it possible to take out impurity bands before blasting, thus avoiding breaking them up in the coal.

The higher output consequent upon operation from the track soon led also to the development of models designed to take over the duties of conventional types of cutting equipment, particularly the shortwall machine. This trend has been particularly noticeable at mobile-loader mines, many of which, especially in the Middle West, have adopted track-mounted cutters as an adjunct to loading machines.

While early-type track-mounted cutters offered a considerable degree of flexibility, they were limited to horizontal kerfs, meaning in general that only one additional free face was available unless auxiliary shearing equipment was used. General development of such shearing equipment, however, does not appear to have followed what would seem to have been the logical order, but rather succeeded the so-called "uni-

versal" machines providing both cutting and shearing with the same bar, although Jeffrey designed a breast machine with a vertical bar in 1898, and Sullivan early used a modification of the puncher to make a track-mounted shearing machine. Possibly the earliest, or at least one of the earliest, universal cutter was the Oldroyd with horn-type bar in a revolving turret-type head in use at the Kingston (W. Va.) operations, Solvay Collieries Co., in 1916. By 1921 the Oldroyd machine had been redesigned to accommodate the chain-type bar, and one of the new types for bottom-cutting and shearing was installed by the Buffalo Eagle Colliery Co., Logan County, West Virginia. Change from one position to the other was made with a power-driven revolving head.

Shearing Coal Studied

Meanwhile, shearing was being investigated by a number of operators with varying results and other methods of increasing lump yield were being tried, including cushioned blasting with rock-dust stemming and snubbing. Designers also were busy developing both shearing and combination cutting and shearing machines. One of the earliest operating organizations to give snubbing a thorough trial was the Union Colliery Co., Dowell, Ill., which about 1925 experimented with the Goodman snubbing machine with two cutter bars, one full and the other half length, brought out a short time earlier, as well as air hammers and snubbing shots. Within the next year Dowell officials brought shearing into the scope of the study, using a shortwall machine turned edgewise and also the Joy caterpillar-mounted shearer, later adopted as standard equipment. The occasion for these measures, as at many other mines then and since, was the adoption of mechanical loading, bringing up the problem of breaking down the face in such a way as would facilitate loader operation and yet insure a good coarse-coal yield.

The snubbing pan, since adopted by a number of mechanical-mining operations, was developed and patented by H. H. Taylor, Jr., and William Smith and installed in the Royalton No. 7 mine of the Franklin County Coal Corporation, Inc., Royalton, Ill., in November, 1927. A number of pans were placed in the undercut, the lower part of the seam was shot down on them, and they were pulled out with the loose coal by a locomotive. Later, a block and tackle was substituted. While snubbing with a pick had been practiced in hand-loading mines many years before, developments in mechanical-loading mines in late years have been concentrated largely on pans, snubbing shots alone, or snubbing shots supplemented by pulling the coal out by hand or loading it out with a mobile loader.

Shooting with liquid carbon dioxide in a steel shell containing a heater element to convert the CO_2 suddenly to a gas—the Cardox system since widely adopted in bituminous mines and used to some extent in anthracite—was tried out at a mine of the Harrisburg Coal & Mining Co., Saline County, Illinois, in 1926. A modification employing compressed air—the Energy Air Miner—was introduced late in 1931 at the Royalton No. 7 mine in the same State. The cartridge in this case included a rupturable disk. Airdox, also employing compressed air, was offered in 1933, one of the first companies to adopt it throughout being the Standard Coal Co., Wheatland, Ind. The Airdox cartridge embodies an internal valve, releasing the air when the feed line is vented at the compressor.

Mechanical coal breakers also have attracted the attention of designers. An early example, brought out in 1921, involved the use of a hydraulic expanding bar inserted in the slots cut in the top of the seam. In 1930, F. W. Whiteside experimented with a power-driven wedge at the mines of the Victor-American Fuel Co., Colorado. The Meyer rubber cartridge, which was pumped full of water to break down the coal, another Colorado development, was demonstrated in the same year.

That part of the mining machine which actually cuts the coal—the bit—has been the subject of much study from the standpoint of standardization of forming, shaping and heat-treating to insure a correctly shaped point and increase the tonnage cut per bit used. In addition to major gains from improved bit-handling practices, new designs, new materials and hard-facing have received increased attention since about 1925. About 1928, a number of companies had adopted hard facing, including the United States Fuel Co., Utah. With facing and heat-treating, primary objectives were reduction in sharpening cost and bit-setting time, and faster and more efficient cutting with reduced power consumption and less wear and tear on the machine. By 1931, several Illinois companies had adopted various hard-facing materials, such as Stellite, Stoodite and Blackor, and the use of these and other types of materials is now widespread.

A number of companies in the Middle West and elsewhere, however, have preferred to heat-treat their bits to prolong the life of the cutting edge, using an oil bath for quenching and a salt bath for drawing. Such a system was well under way at the Dresser mine of Walter Bledsoe & Co., Terre Haute, Ind., early in 1933, under the direction of James Hyslop, and since has been the model for a number of others.

Alloy and special steels, while often suggested, have as yet made little headway in the construction of standard cutter bits, but have, however, found a growing field in special bits, of which the Link-Belt double-end type of 1920 was an early example. Double-ended bits since 1930 include the Cincinnati "Duplex," Prox "Automatic," and Bowdil. The latter, in particular, has found wide acceptance in the Rocky Mountain region in the last two or three years. Jeffrey, in 1935, devised the three-pointed star bit and chain. The several types of these bits are designed to be used without resharpening and also to reduce bit-setting time through the longer-wearing qualities of the special steels.

Pickhammer Comes In

The pickhammer, widely used in Europe, began to attract increased interest in 1929, which was reflected in trials in western and central Pennsylvania. The pickhammer apparently was pioneered some years before by the Southern Coal & Coke Co., Alabama, which in 1929 was employing this light pneumatic equipment to break up coal on a long face after undercutting prior to loading it on a conveyor. At the Aldrich mine, in the same State, the Montevallo Coal Mining Co. employed pickhammers in 1929 for making a side shear in headings after undercutting. Initial experiments in central Pennsylvania were followed by the adoption of this equipment by a number of mines, led by the Berwind-White Coal Mining Co., with the result that central Pennsylvania wage agreements since 1934 have carried a pickhammer rate, now 78c per ton.

In 1931, J. F. Joy offered his coal saw and hydraulic breaker pad for "powderless" mining. The saw was made with two blades for dividing the coal into blocks by horizontal and vertical cuts. This construction, however, was soon abandoned for the single blade, offered first in a floor-mounted type and then in both floor- and track-mounted types. Early ma-

jor users of the coal saw included the Black Star and Pioneer coal companies, Kentucky; Lake Erie Mining Co., Peoria, Ill., and the Crescent Coal Co., Evansville, Ind.

In addition to the thin saw blade, the track-mounted coal saw included hydraulic motion control and a revolving cutter head which enabled the machine to cut at any level and make a straight shear cut on either side of a place of the usual width, in addition to snubbing, angle-shearing and other cutting duties. All these motions and cutting possibilities were incorporated in the 7AU cutting and shearing machine by the Sullivan Machinery Co., which took over the Joy saw. Brought out in 1935, and since installed by a number of companies in Illinois (including Chicago, Wilmington & Franklin and Wasson), West Virginia (Valley Camp and Christopher) and elsewhere, the 7AU machine normally is fitted with a thin-kerf bar.

New Problems Met

While track-mounted equipment has continued its gains, the shortwall and longwall in certain cases still remains the standard cutting unit, particularly in very thin seams. In addition, conveyor operations, where track normally is dispensed with, find the shortwall or longwall to date the only type of chain cutting machines available. Some operators have met the problem by installing a standard cutter in each working place where the room-and-pillar system is employed, while others move the machine from place to place. Available space between the coal and the conveyor also enters the problem.

As solutions to the above problems, two new cutters were developed in 1936. The Sullivan "Buddy," one of the new units, is a light-duty shortwall especially designed to remain in one working place. The other, the Jeffrey 41–A mining machine with remote contactor control on a separate skid, thin-kerf bar, and star bits and chain, operates on the bottom and is designed to remain in the working place. It is available with a cutter bar on the bottom or on the top. In the latter case, height of the bar is adjustable.

The past three years also has witnessed a number of developments widening still further the cutting field. These include: cutting machines designed to load or gob the cuttings; track-mounted machines with double bars for cutting out refuse bands, used by the Rochester & Pittsburgh Coal Co., Pennsylvania; slack-cutting machines, including a recent drum-type longwall unit making a 26-in. kerf, used where all the product of thin seams can be employed for metallurgical purposes; a recently developed auger cutter, which handles like a breast machine and employs eleven augers with interlapping cutter points; and a sharp increase in application of thin-kerf cutter bars. Double cutting has been introduced in the Paris (Ark.) field in the last three years. At one mine, the bed is first undercut in the hard shale or clay below the coal. Then, after the coal falls, another machine cuts the bone and shale off the top of the coal. This system is employed with scow mining on a long wall.

In the province of drilling, the last five years or so has seen a wide increase in the use of pick-type bits and holders to eliminate the transportation of auger steel in and out of the mines and make bit sharpening largely a matter of using a file. The spread in the use of Cardox and air shooting, involving the use of large-diameter holes to accommodate the steel shells employed, has been met by the use of molefoot and similar bits on regular auger steel in addition to the development of augers with a cylindrical shank on which spirals are welded, since applied to augers used for drilling the regular-sized hole because of the increased strength available without adding greatly to weight. In the anthracite field, the pneumatic drill has been steadily increasing for many years, accompanied in more recent times, particularly at mechanized operations where current is available, by a rising use of electric types.

Substitution of tamping plugs of various types for the conventional stemming material in shotholes was a 1935 development at a number of mines. Experiments with the Heitzman rubber plug were carried on by the Lehigh Navigation Coal Co., Lansford, Pa., and a number of companies in the Northern anthracite field began to work with the Voortman concrete plug, a German innovation. Usually the Voortman plug is placed some distance away from the charge to give a cushioning effect. A number of bituminous operations, notably in Utah, began experiments with both types of plugs in 1936.

STRIPPING

STRIP MINING is as old as the coal industry, as primitive miners, working along the outcrop, could do little else but quarry their output, at first disposing of the spoil by hand and later employing wheelbarrows and carts. When the overburden became too heavy for hand removal, horses or other draft animals with plows and slip scrapers were adopted. Still later, the wheeled scraper came into use in heavier work and thicker overburden.

Traces of wheelbarrow runs used in working early strippings still may be seen in the anthracite region, where the first production on a commercial scale came from a strip pit—the old "Quarry" mine, on what is now the property of the Lehigh Navigation Coal Co., Summit Hill, Pa. Coal was discovered at this point in 1791 by Philip Ginter, and by 1820 stripping was being done with cattle and scrapers, continuing for some years until increasing depth forced a change to underground methods. After Summit Hill and other contemporary operations, anthracite stripping apparently lapsed, except for isolated instances, until about 1875, when it took a new lease on life in the Middle and Southern fields.

Mechanization of stripping in the United States is the outgrowth of the invention of the steam shovel in 1839 by Otis, who was killed trying it out. An Otis shovel was applied to bituminous stripping in 1877 by J. N. Hodges and A. J. Armil, who started a stripping with teams, plows and scrapers in the Pittsburg (Kan.) field in 1876. In 1881, C. Pardee embarked on an extensive stripping program at the Hollywood colliery, near Hazleton, Pa., and here the first anthracite steam shovel, with 1-cu.yd. dipper, was introduced by Capt. William I. Conner, who started the work, and L. E. Klotz, the contractor.

At the time of the Hollywood shovel, according to one authority, it was considered that 1 ft. of overburden could be removed with profit per foot of coal, even though partly mined. By 1911, as much as 3 ft. of overburden, 60 per cent rock,

was being removed. At present, depending upon the bed (virgin or partly mined), quality of coal, character of overburden and adaptability to casting, the ratio of overburden to coal in anthracite stripping ranges up to more than 7 to 1.

From early times, the stronghold of anthracite stripping has been the Southern and Middle fields, where the difficulty of mining the outcrops of steeply pitching beds from underground at a reasonable cost has favored this recovery method. Another factor, of heightened importance in late years, was the possibility of obtaining coal at less than the deep-mining cost. Thinner coal and, as a rule, light pitches, making crop strippings unnecessary in many cases, have kept the Northern field tonnage down (maximum to date was 19.3 per cent of the total in 1933). In 1931, however, with the general rise in strip mining, the Northern field began to increase its share of the total.

The precursor of the modern stripper — Wright & Wallace's first dry-land dredge

Shovel Use Increases

By 1914, a number of 2½-cu.yd. railroad-type stripping shovels were in operation in the anthracite region, usually with overburden cars of less than 5 cu.yd. In that same year, a full-revolving electric dragline with a 3½-cu.yd. dipper was installed by the Locust Mountain Coal Co. at its Shenandoah stripping. By 1920, this company was also operating seven steam and electric shovels, and at the end of the year had removed over 3,000,000 of the 4,100,000 cu.yd. of overburden in its East Basin stripping. Also in 1920, an electric dragline with 3½-cu.yd. bucket and 128-ft. boom was stripping to a depth of 86 ft. at the Mammoth bed operation of the Lehigh Navigation Coal Co., near Nesquehoning. In recent times, this type has stripped to 175 ft., the maximum at another Nesquehoning operation of the same company.

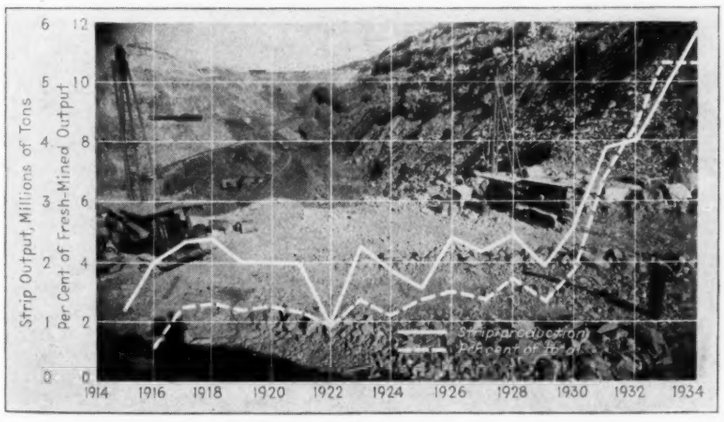
In 1925, a full-revolving electric shovel with 6-cu.yd. dipper was started at the Crystal Ridge stripping, Cranberry Creek Coal Co., near Hazleton. This stripping, completed, except for a 70-ft. extension, in 1934, involved the removal of 5,200,000 cu.yd. of overburden in standard-gage, 30-cu.yd. air-dump cars to recover 665,000 marketable tons of coal. In that same year, Lehigh Navigation embarked on a new stripping program at Summit Hill which eventually will involve the removal of 13,000,000 cu.yd. of overburden, nearly all hauled out of the pit in 30-cu.yd. cars, to recover 4,600,000 tons of marketable coal. Equipment includes an electric shovel with a 7½-cu.yd. dipper built up from 6 cu.yd. At the end of 1935, overburden removed totaled 7,300,000 cu.yd.; coal, 2,200,000 tons.

The tempo of anthracite stripping since 1930 has been marked by a rapid increase in the use of draglines, adoption of automotive hauling equipment and installation of larger stripping units. The walking dragline entered the anthracite picture in 1930 with the installation by the contractor of a 6-yd. machine with 160-ft. boom at a Northern-field stripping of the Hudson Coal Co., followed by a similar unit at a Pittston Co. operation. In 1934, the same contractor started a walking dragline with 10- and 12-cu.yd. buckets near Mahanoy City, Southern field.

Ability to cast spoil and thus eliminate hauling and, in many cases, recovery of the coal with only half the excavation have been the major factors in dragline growth in late years, considerably extending the application of stripping to steeply pitching beds. Trucks, tractor-trucks and trucks with caterpillar running gear have been adopted to save laying and moving tracks. They also permit stripping in isolated sections where either the conventional standard- or narrow-gage track would be prohibitive in cost. Stripping equipment for such service generally is powered with gasoline or diesel engines, and such engines also have been widely applied in general service in addition to electric and steam drives.

Bituminous stripping was cradled in the Danville district of Illinois. Kirkland, Blankeney & Graves opened a plow-and-scraper strip mine at Grape Creek, south of the city, in 1866, and in 1875 Michael Kelly started another operation at Hungry Hollow. In both cases, stripping usually was done in the summer by plowing and scraping and the coal was hauled out in wagons in the winter. As previously stated, Hodges and Armil started a team-scraper operation in 1876 near Pittsburg, Kan., where the coal thickness was about 3 ft.; overburden, 8 to 12 ft., renting an Otis shovel in 1877. Overburden of this thickness was limited, however, and as the

Anthracite stripping progress is marked by a sharp rise since 1931



When steam was king—two Sunlight strippers meet in 1916

boom was too short for thicker overburden, the shovel was returned after about three years.

The second mechanical stripping operation was opened near Danville in a river bottom known as the Missionfield. The coal was owned by the Consolidated Coal Co. of St. Louis. Overburden thickness varied from 10 to 15 to 35 ft.; coal thickness was 6 ft. Wright & Wallace accepted a contract to strip the area, and as steam shovels had not been produced in sizes suitable for economical stripping, they bought a Marion dredge, minus the hull, which they placed on wheels and started to work in 1885. Constructed of wood and with a boom about 50 ft. long, the dredge made a cut about 20 ft. wide. Removal of 400 cu.yd. of overburden in 10 hours was considered record making. A short time later, hampered by the slowness of the dredge, narrowness of the cut and flooding of the pit, the contractors installed a second dredge with a 1¼-cu.yd. dipper in an effort to deliver the specified tonnage. Soon afterward, a third machine with a 1¼-cu.yd. dipper and 65-ft. boom was installed. In 1888, the machines were taken over by the coal company, which abandoned them because of wear in 1890.

Butler Bros., who had previously employed draglines in ballast-burning in the Southwest, next undertook the stripping of the Missionfield, starting work with three draglines (¾, ⅞ and 1 cu.yd., respectively) in 1890. The machines, self-propelling in type, worked on a track on the bank and were equipped with horizontal non-swinging booms about 80 ft. long. In operation, the bucket was dropped down in the pit, pulled up to the machine and then run out to the end of the boom, where it was dumped. These machines made parallel cuts about 20 ft. wide, and first were used for stripping only, which they did with ease as long as no hard material was encountered and the overburden thickness was not too great. Soapstone, increasing thickness and floods, however, soon forced a move from the original site and one machine was abandoned. On the new site, the machines were worked in tandem, one stripping and the other digging and loading the coal into railroad cars—the first machine loading of strip coal. Here again hard material appeared, eventually forcing stoppage of operations.

Butler Bros.' belief in the dragline was undiminished, however, and in 1900, financed by the coal company, they installed a much larger machine with a 135-ft. (later 115-ft.) boom and three 2-cu.yd. buckets—for dirt, rock and coal. The rock bucket, however, proved a failure in soapstone without drilling and blasting and about two years later the firm gave up, although the machine was kept at work by others until about 1907. In 1903, a Schenable full-revolving dragline was installed by Donovan and associates, also to be abandoned after bringing its various owners financial loss.

The year 1904 witnessed the birth of a combination shovel and stacker. Such a machine, designed by George E. Turner, was installed on a tract of the Consumers Coal Co., Danville, Ill., by George W. Prutsman, the contractor. The shovel, with a short (35-ft.) boom and 2-cu.yd. dipper, deposited the spoil in a hopper feeding a 105-ft. conveyor on a boom. The machine had a wood frame and was mounted on four 4-wheeled trucks—without, however, any equalizing device for keeping the frame level. About 1907, after Prutsman and his successors had given up the attempt, the coal company took over the machine and rebuilt it with steel, using it until 1913 without profit.

Another early backer of the shovel and stacker idea was Morton E. Pugh, who envisioned units in which the stacker and shovel were combined and also units in which they were separated on parallel tracks. Several attempts were made at operation in Iowa, but without success. A crusher to break down the spoil before it went on the belt was one of Pugh's ideas. The conveyor-type stacker still intrigues strip operators, but the difficulties in either breaking down the large pieces of hard material or designing a conveyor that would accommodate them have so far militated against the installation of such units.

Kentucky Strips in 1907

In 1907, stripping was started near Lily, Ky., to recover the 28-in. Jellico seam under 6 to 8 ft. of overburden. Two Vulcan shovels, one for stripping and the other—probably the first such shovel application—for loading, were employed. The stripper, of the railroad type, had a 2½-cu.yd. dipper and a 28-ft. boom. The loading machine, mounted on traction wheels, had a 1½-cu.yd. dipper and a 22-ft. boom. This operation, however, lasted but a few months. In 1910, two Vulcan revolving shovels with 1½-cu.yd. dippers and about 50-ft. booms were installed by Patrick Durkee and Joseph Stephenson, near Pittsburg, Kan. Later in 1910, a Browning full-revolving shovel with 2-cu.yd. dipper and 50-ft. boom was installed in the Missionfield, but light construction wrecked it in six months.

Up to 1911, stripping had been attended with more grief than profit, but nevertheless the foundations of present practice had been laid. Two years before, Grant Holmes and W. G. Hartshorn, of Danville, had concluded that the ultimate stripper should be a long-boomed self-propelling full-revolving unit built to withstand the strains encountered in stripping, thus combining the dig-

ging power and dumping range of the Turner-Prutsman conveyor shovel, the ability to dig and dump in any direction of the Schenable dragline and the self-propelling features of the Butler draglines. The first such machine, Marion-built, with 3½-cu.yd. dipper, 65-ft. boom and 40-ft. dipper stick, went into operation in the Missionfield in the spring of 1911, a few months before the first issue of *Coal Age* came off the presses. The shovel was equipped with hydraulic equalizing jacks, patented by Mr. Holmes, to keep the frame level and prevent the twisting and breakage previously encountered. In the following year, the first heavy revolving-type Bucyrus shovel, with three-point suspension and screw jacks for keeping the frame level, was erected.

Strip Problems Linger

The arrival of the modern stripping unit in 1911 did not, however, solve all the problems of the industry. Strip-mined coal, under early production conditions, had, perhaps deservedly, a bad name and generally sold at prices substantially under those for deep-mined coal. The output usually came from near the outcrop or from areas under shallow cover containing little or no material dense enough to protect the bed, and in most cases was loaded directly into railroad cars without preparation.

The prejudice against strip-mined coal engendered by these early practices—an inevitable result of the state of the art in those days—lingered for many years and still persists to a limited extent even though the preparation and quality pictures began to change after 1911, with the result that coal comparing favorably with deep mines now is being uncovered and strip operators at present are among the leaders in the adoption of modern preparation aids.

Increased use of modern stripping units after 1911 soon made it possible to remove overburden up to 60 and 70 ft. in thickness and to handle material containing considerable rock—both tending to assure higher-quality coal through greater protection of the bed. Moreover, the new excavating machines, with other auxiliaries, enabled the operator to keep the coal clean while it was being loaded. And within a few years after 1911 strip operators were building tipples comparing favorably with or even better than those at deep mines. Furthermore, stripping companies in the Middle West and Southwest initiated the new cycle in mechanical cleaning in those regions since 1930.

In the 25 years since the 3½-cu.yd. Missionfield shovel was installed, dipper capacity has been increased nearly ten times to 32 cu.yd. In fact, it was no later than 1912 when the Missionfield machine was eclipsed by a shovel with a 5-cu.yd. dipper, 90-ft. boom and 54-ft. dipper stick installed by the Ellsworth-Klaner Construction Co., Pittsburg, Kan., followed by a similar unit in 1913. By 1914, the two together had moved 6,700 cu.yd. per day (probably one shift). Cost of these shovels ready for operation was reported to be $50,000, compared with $325,000 to $375,000 for the present-day equipment carrying dippers of 30 cu.yd. or more.

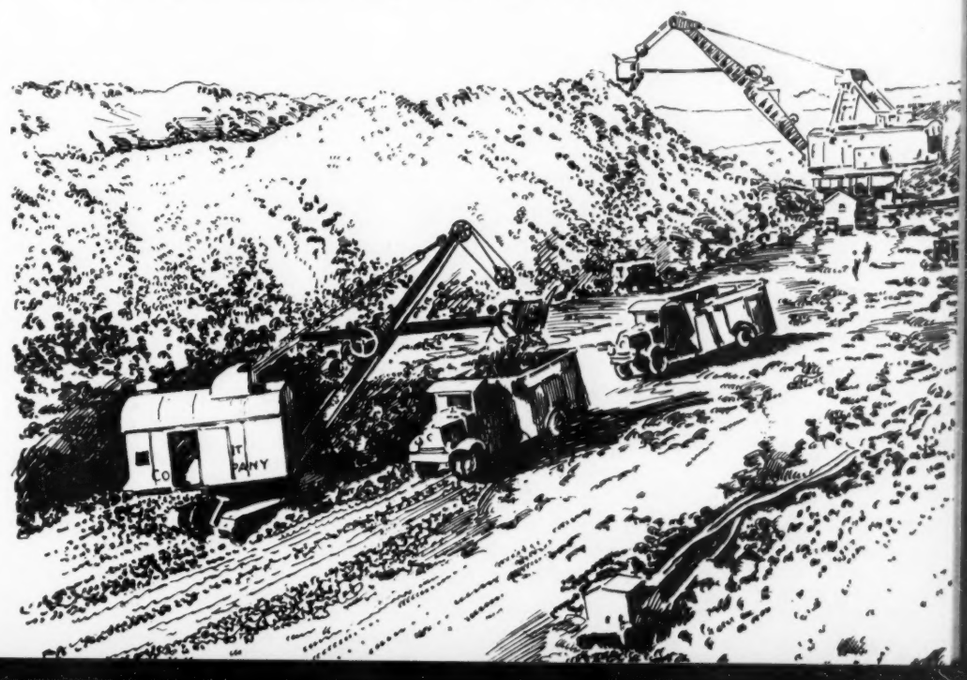
Possibly the earliest revolving coal-loading shovel was that installed in 1912 by the T. J. Forschner Coal Co., Linton, Ind. About 1913, another Kansas practice—lifting coal out of the pit by crane or derrick—was adopted by a number of operators, who employed traveling cranes to lift skips, or car bodies, holding 5 tons of coal, depositing them on trucks on a track on the bank. At the loading station, the skips were dumped into railroad cars by derricks. Later, cars were handled bodily or bottom-dumping skips or special "bank machines" were employed—a practice still current at a number of pits. Around 1913, also, a number of Pittsburg field shovels were equipped with lights for night operation.

By 1914, strip output had risen to 1,280,946 tons (Illinois, Indiana, Kansas, Missouri and Oklahoma), or 0.3 per cent of the national tonnage. In 1934, strip production was reported from eighteen States, according to the U. S. Bureau of Mines, which showed a total output of 20,789,641 tons, or 5.8 per cent of the total output. Included in the 1934 total was 115,778 tons from horse-stripping operations. The rise in stripping has been accompanied by major changes in the production picture in certain regions—Kansas and Missouri, for example—where the increase in shovel mining has sharply restricted the activity of deep mines, leaving them little but the domestic market in the winter season as a rule.

By 1915, a number of 6-cu.yd. shovels were in operation and one, at the Henryetta (Okla.) mine of the Alko-Nak Coal Mining Co., with 85-ft. boom, was reported to be averaging 5,000 cu.yd. per nine-hour day. Coal was hauled out of the pit in 2-ton cars. In that same year, the Piney Fork Coal Co., Smithfield, Ohio, installed an electric stripper (General Electric a.c. motors and controls) with a 90-ft. boom and 6-cu.yd. dipper. Although electric shovels had been developed around 1912, this apparently was the first of any size used in coal stripping. Next year, a similar unit with 8-cu.yd. dipper, 90-ft. boom and 45-ft. dipper stick was installed at Rush Run, Ohio, by the Beech Flats Coal Co. It included one-man control of all operations.

Although the stacker was an early development, few installations have been attempted. One, according to reports, was a Hamilton stripping conveyor put in service in 1919 by the Vinton-Jackson Coal Co., Ohio. The machine consisted of a conveyor mounted on a long boom fed from a hopper into which one or two stripping units dumped. Reduction in shovel size and in swinging and dumping time were the principal advantages claimed. The only stacker

Electric power and truck haulage characterize Sunlight in 1936



in recent times was that installed at the Mark Twain mine, Huntsville-Sinclair Mining Co., Huntsville, Mo., in 1934. In this stacker, used in the recovery of two seams by handling the rock between them, a 4-cu.yd. car operates on tracks on an inclined bridge. The car, after being filled by the shovel, is pulled out to the end of the bridge by a hoist, where it dumps automatically.

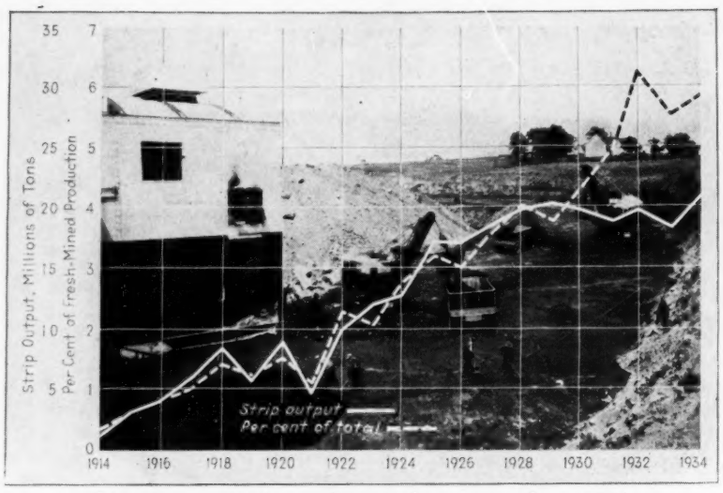
Application of d.c. equipment with variable-voltage control to stripping shovels started around 1923 and was employed on a 6-cu.yd. stripping shovel-dragline and 7-cu.yd. loading shovel installed at the Colstrip (Mont.) operation of the Northwestern Improvement Co., opened in 1924. Even the haulage at this operation was electrified with 60-ton storage-battery locomotives handling standard railroad cars. It was not until about 1927, however, that application of d.c. equipment to the usual loading shovels started.

Many Advances in 1926

The year 1926 was notable for several developments influencing subsequent stripping practice. In that year, in addition to three 6-cu.yd. strippers, the United Electric Coal Cos. installed an 8-cu.yd. machine with 90-ft. boom and 56-ft. dipper stick mounted on caterpillars at its new Cuba (Ill.) operation. Although caterpillar traction had been employed on loading shovels for some years, this was the first application to large-sized stripping units. The new unit, equipped with four hydraulic equalizing jacks, handled 176,079 cu.yd. of overburden in July, 1926. Five-ton rotary-dump cars were employed for coal hauling. In that same year, the Pyramid Coal Corporation, Pinckneyville, Ill., installed a bulldozer for cleaning off the top of the coal.

In Indiana in 1926, the Enos Coal Mining Co., Oakland City, started the use of L.O.X. (liquid oxygen) for blasting overburden, since adopted by a number of stripping organizations.

Installation by the Northern Illinois Coal Corporation of an electric shovel with a 12-cu.yd. dipper, 90-ft. boom and 60-ft. dipper stick in the old Braidwood-Coal City-Wilmington field, in northern Illinois, was a feature of 1928 developments. With this shovel, the company inaugurated tandem dragline and shovel operation to increase yardage, using a dragline with a 150-ft. boom and 6-cu.yd. cast manganese-steel bucket to remove the surface material in front of the shovel. Contemplated production of the two machines in overburden averaging 30 to 35 ft. was 400,000 to 500,000 cu.yd. per month. Along with 40-ton Koppel air-dump cars for coal transportation, the company adopted the ground-cable system of power transmission. Later in the year a 10-cu.yd. dragline-12-cu.yd. shovel unit started on the property.



Bituminous stripping makes steady progress from 1914

In the years immediately preceding the Northern Illinois installation, a few companies had employed draglines to help out their shovels in making box cuts, and even farther back (1912-13), the Danville Brick Co. had used a dragline-shovel combination, the shovel digging the overburden and depositing it at one side, where it was picked up by the dragline operating from the spoil bank. A substantially similar system (dragline taking spoil dug by the shovel) has been employed by a number of companies in late years, including the Sternberg Coal Corporation, Boonville, Ind. (August, 1936, *Coal Age*, p. 325.)

The Northern Illinois shovel was followed in 1929 by a machine with a 16-cu.yd. dipper, 85-ft. boom and 60-ft. dipper stick at the No. 10 mine, Pittsburg & Midway Coal Mining Co., Barton County, Missouri. Total weight of this machine was 1,005 tons, but it soon lost its heaviest distinction with the installation of a shovel with a 120-ft. boom and 82-ft. dipper stick at Fidelity No. 11 mine, United Electric Coal Cos., Duquoin, Ill., later in the year. Although equipped with only a 15-cu.yd. dipper, the Fidelity stripper was designed for a 20-cu.yd. unit and had a total weight of 1,750 tons. It was accompanied, in addition to other equipment, by a 3-cu.yd. coal loader.

The year 1928 brought trailer haulage to the Pittsburg (Kan.) field with the installation of a number of United drop-bottom units by the Alston Coal Co. Large-scale haulage with trucks was even earlier, however, the Pittsburg & Midway Coal Mining Co. adopting this form of transportation at its Moundville (Mo.) mine in 1927, following it up at its No. 10 mine about 1928 with the first Sanford-Day 8-wheel drop-bottom strip-pit cars, the forerunners of the bottom-dumping trailers offered later by the same company.

Trailer haulage has since been widely adopted and the size of units has steadily increased to 25 to 30 tons, the capacity of the Austin-Western trail cars installed at the Bobolink operation of the Binkley Mining Co., Seeleyville, Ind., in 1935, and later at other operations. Although trailers are in the majority, dump trucks are used in numbers by smaller strip operations, and in 1935 the truck was adopted by the Sunlight Coal Co., Boonville, Ind., which, however, designed a special W-shaped 15-ton body dumping to both sides.

Experimental work eventually resulting in the development of the now widely used sidewall drill was begun by W. H. Stewart, general superintendent, Central Indiana Coal Co., Linton, Ind., about 1930. At about the same time, a Bucyrus-Erie balanced (counterweighted) hoist was installed on a shovel with a 16-cu.yd. dipper at the Tiger (Mo.) mine, Hume-Sinclair Coal Mining Co. In 1933, the Midland Electric Coal Corporation, Farmington, Ill., installed an electric shovel with a 20-cu.yd. counterweighted manganese-steel dipper with renewable teeth, supplementing it with a 5-cu.yd. loading shovel, 50-ton automatic drop-bottom cars and 90-ton rod engines.

Redesign of dippers to increase capacity also started in 1933. Late that year, the Pittsburg & Midway Coal Mining Co. replaced a 16-cu.yd. cast dipper with a 20-cu.yd. Bucyrus-Erie all-welded carbon-steel dipper. Welded construction and addition of a balanced hoist to the shovel made possible the increase in capacity. Early in 1935, the first Bucyrus-Erie dipper of all-welded "Man-Ten" high-strength steel was installed by the Pyramid Coal Corporation, Pinckneyville, Ill. Welding, high-strength steel and addition of a balanced hoist permitted increasing dipper size from 12 to 18 cu.yd.

Use of aluminum-alloy dippers started with a 5-cu.yd. coal-loading dipper on a Hume-Sinclair shovel in January, 1934, replacing the former 3½-cu.yd. unit. In August, 1934, a 16-cu.yd. Marion-built aluminum-alloy stripping dipper was installed by the Northern Illinois Coal Corporation, replacing a 12-cu.yd. steel dipper. In 1935, the Commercial Fuel Co., Pittsburg, Kan., purchased a composite dipper (American Manganese Steel Co. design) incorporating aluminum alloys and high-tensile and manganese steels with a capacity of 15 cu.yd. and a weight of 32,940 lb. to replace a 12-cu.yd. cast dipper.

Dipper size took another upward leap in 1935. The Northern Illinois Coal Corporation in that year installed a Marion 5560 shovel with a 32-cu.yd. aluminum-alloy dipper, 104-ft. boom and 65-ft. dipper stick. The new Bobolink mine of the Binkley Mining Co., Seeleyville, Ind., was equipped with a Bucyrus-Erie 950B stripper with 30-cu.yd. all-welded Man-Ten steel dipper with balanced hoist, 105-ft. structural-type boom and 64-ft. cylindrical dipper stick with rope crowd (*Coal Age,* April, 1936, p. 131). Since these two units a number of strip shovels with dippers of 30 cu.yd. or over have been installed or contracted for.

Another development in bituminous stripping since 1930 has been the widespread adoption of small draglines, many with gasoline, diesel or semi-diesel engines, by concerns operating relatively small or isolated tracts under light cover (approximately 35 ft. or less). These units may be, and often are, used alone or in some cases in combination with shovels.

TRANSPORTATION

COAL-MINE transportation has for many years been based on the use of cars and tracks. This still is the major method, although other means, particularly the conveyor, have come into increasing prominence in the 25 years since the first issue of *Coal Age*. Most of the nation's output, however, continues to roll on wheels, but the character of the wheels themselves, the track on which they operate, the cars they carry and the motive power which keeps them turning have in many cases been subject to material changes.

Mine-car capacity has steadily increased. This increase is one of the factors in the decline in use of animals for haulage and the adoption of the locomotive, which can handle a heavier load and make better time over long hauls. Resistance to movement has been attacked by installation of anti-friction bearings. Steel and alloy-steel car construction has progressed at the expense of wood. Spring suspension and spring draft and buffing gear have been adopted to smooth operation and track-construction standards have been revised upward to approach railroad practice to the accompaniment of strict control of equipment movement through a central office to promote efficiency.

The earliest method of transporting material from mine workings was in a tray or basket. Next came wooden sleds, or baskets with runners, usually drawn by boys or women and extensively used in the early days in Great Britain. Wheelbarrows probably were the next means of transportation, to be followed by the buggy, still used in many anthracite and some bituminous mines in the United States where introduction of standard-sized cars is too costly. Early buggies ran on the bottom or on wooden rails, as cast-iron tram plates for wood rails—the predecessors of wrought-iron and steel rails—were not, according to Foster and Cox, introduced into England until 1767.

Following enactment of a law prohibiting the employment of women, or of children under 10 years of age, British mine owners after 1843 adopted the Shetland pony as a substitute for the "putters," or trammers, employed to convey the coal from the face to the main roads. Horses were used where seams were thicker. The earliest use of mechanical haulage underground was about 1812 or 1813, when George Stephenson was reported to have altered an engine to make it haul cars up an inclined plane to the shaft. About 1841, according to Galloway, "the haulage of coal by ropes was greatly facilitated by the introduction of light, round, iron-wire ropes."

Transportation evolution in the United States apparently was substantially similar to that in England, except that women were seldom employed in mines and mules early took first place among haulage animals. In West Virginia, according to W. B. Devaney ("Coal-Mine Haulage in West Virginia"), records of the property now owned by the Cannelton Coal & Coke Co. go back to 1796. The cannel and bituminous seams at that place were opened by Coone, Pickett & Co. in 1857, and prior to the Civil War slaves carried the coal out in sacks or baskets. The slaves were replaced by oxen pulling sleds, which in turn gave way to the mule in 1870.

Horses and ponies were early employed to haul coal, and still are used, although far outnumbered by the mule. Overman, in 1852, called attention to still another type of animal haulage—dogs and carts—which he stated to be in general use in coal mines in the western United States at that time. Dogs also have been employed in other regions, notably Illinois and Ohio.

Steam in Mines in 1870

Mechanical transportation began in the United States around 1870. Adoption of rope haulage is placed by at least one commentator at about that time, and two of the earliest steam locomotives for underground use were delivered to the Wilkes-Barre (Pa.) Coal & Iron Co. in that year. The units weighed 7 tons and had a tractive effort of about 3,000 lb. Use of steam locomotives underground in the bituminous field goes back as far or farther, an early example being the locomotive installed at the Cannelton Coal & Coke Co. property in 1874.

Smoke and fire hazards with the steam type led many companies to adopt compressed-air locomotives. The first such, a Baldwin machine, was installed, it is reported, at the Old Eagle colliery of W. H. Brown's Sons, near Brownsville, Pa., in 1882.

The locomotive, weighing 8 tons, was said to have done the work of twenty mules and to have hauled a gross load of 60 tons up a 1.9-percent grade. The first compressed-air locomotive in the anthracite region, built by H. K. Porter, went into the bottom lift of the No. 6 shaft of the Susquehanna Coal (now Collieries) Co., Glen Lyon, in 1895. Weight of the original Glen Lyon unit was 8 tons; cost was $2,700, f.o.b. Pittsburgh. The two-stage compressed-air locomotive was placed on the market in 1908.

The electric locomotive, however, soon sounded the knell for both steam and compressed air underground, although scattered installations of both types still are in use. The first electric locomotive for surface work was exhibited at the Berlin trade exposition in 1879, followed by an installation at the Royal mines, Saxony, in 1882. Another Susquehanna operation introduced the electric locomotive into the coal mines of the United States, placing the first machine, the Union Electric Co. "Pioneer," in the old Lykens Valley Tunnel in 1887. Total cost was $4,700, including the generating plant. The conductor was an iron T-rail spiked to timbers. An early report stated that the unit had handled a trip of 31 cars weighing almost 150 tons. Grade was approximately ¼ per cent in favor of the loads.

The second anthracite electric locomotive, built by the Thomson-Houston Electric Co., was installed at the Hillside colliery, near Scranton, in 1889. This locomotive received current through a trolley wheel from a No. 0 hard-drawn copper wire suspended from the roof. From this machine the Thomson-Houston Co. developed the terrapin-back, one of the first of which was installed at No. 8 mine, Union Pacific Coal Co., Rock Springs, Wyo., in 1892. This locomotive, which saw 34 years of service, was inducted into the Union Pacific Old Timers' Association in 1929 and christened "Charlie Smith," after the first man to operate it. It now stands on a concrete pedestal in front of the Old Timers' Building in Rock Springs.

Ancient coal transportation in Scotland

Ohio Gets Locomotive

The first electric locomotive to be installed at a bituminous mine was the "George Upson," built by Jeffrey and put in service at the Shawnee (Ohio) mine of the Upson Coal Mining Co. in 1888. Weighing 2 tons and equipped with a 20-hp. motor, the unit operated off two galvanized-iron pipes mounted on posts. The first electric locomotive in West Virginia, weighing 5 tons and also using pipe conductors, was installed by the Thurmond Coal Co. in 1889. The first Goodman bi-polar locomotive went to the Norfolk Coal & Coke Co., Maybeury, W. Va., in 1895.

In Illinois, the first electric locomotive, built by the Sperry Electric Mining Machine Co., went into the No. 3 mine of the Chicago, Wilmington & Vermilion Coal Co., Streator, in 1888. After several months, this unit, equipped with eight driving wheels and a 30-hp. motor, was replaced by an 8-ton unit with eight wheels on two bogey trucks, each wheel geared to the armature of a 60-hp. motor. Another early locomotive, now little used, was the rack rail, first brought out by Morgan-Gardner in 1899. In 1899, the Odin Coal Co., Odin, Ill., installed the first two-motored Goodman locomotive.

All early locomotives operated off a trolley system and were used for haulage, although it was not long until their application for gathering service was considered, bringing up the question of a substitute for stringing wire in working places and leading to the development of battery, cable-reel and gasoline types. On the battery side, Brush and Faure, working independently, had produced pasted-plate cells in 1880, and Edison perfected the nickel-iron-alkali cell early in this century.

The first storage-battery locomotive was tried in the Trafalgar colliery, England, in 1886. Initial work on the storage-battery locomotive in this country is credited to the predecessors of the Pocahontas Fuel Co., notably the Pocahontas Collieries Co., which started work in 1895 and, after building several unsuccessful machines, purchased a Jeffrey battery unit in 1899 with a weight of 4 tons, a drawbar pull of 1,000 lb. and a speed of 8 m.p.h. Apparently, this unit followed closely installation of a Baldwin-Westinghouse locomotive by the Southwest Virginian Improvement Co., another early Pocahontas Fuel Co. operation, as the Southwest Virginian machine commonly is described as the first. A combination unit weighing 9,000 lb. and equipped with two 10-hp. motors, it was designed to haul one 9,000-lb. loaded car on the level when operating on the battery.

About 1898 or 1899, Anaheim, of the Southwest Virginian organization, evolved the first cable-reel locomotive, consisting of a trolley unit carrying on the top a reel operated by a hand crank. Probably the earliest locomotive with a mechanically driven reel was developed in the Pocahontas Collieries Co. shops in 1900 after Walter O'Malley, Bernard Quim and Walter Baker had evolved the idea of a double cable. The locomotive was christened the "Wampus," and the reel, mounted vertically on the side, was driven from a friction wheel dropped down on the driving wheels. About 1902, the chain-and-sprocket drive was devised, and shortly afterward, H. W. Shaffer, of the Southwest Virginian company, developed a floating motor-driven reel.

Gasoline Used Early

Gasoline locomotives, while never used in large numbers, were an early haulage development. The first, with a 20-hp. engine, was built by W. E. Prouty in 1898, and installed in the Earlington (Ky.) mine of the St. Bernard Mining Co., where it was used about a year. Activity in gasoline locomotives, particularly in the Middle West, continued until about 1920, but exhaust fumes militated against their general use. Within the past year, however, diesel locomotives, used in numbers in European mines, have been considered by a number of engineers.

The electric locomotive has shown a steady growth since its inception, with a corresponding decline in the use of stock, although animals still are employed in comparatively large numbers. Locomotive activity since 1911 has been directed largely

toward increasing motor horsepower per ton, developing larger single units and tandem machines for main-line service and low types for thin seams, and in revising speeds upward in main-line units and downward in gathering units. As a rule, early locomotives were designed with 7 or 8 hp. or less per ton of weight. With increasing duty, horsepower has been increased to 10 for machines up to 8 to 10 tons; 12 for machines up to 15 tons; and 15 for locomotives of 13 tons or more. Speed of main-line units on long hauls has been increased in some instances to 12 to 15 m.p.h., while the speed of many gathering units has been reduced from approximately 6 or 7 to 3½ or 4 m.p.h.

Heavy Units Start Early

Heavy-duty haulage locomotives apparently were early on the scene as a 22-ton unit went into service in 1896 and a number of 15- to 25-ton types were being offered in 1913 when the Carnegie Steel Co. installed two tandem units, each made up of two 15-ton Baldwin-Westinghouse type locomotives, at Charleroi, Pa. These locomotives were designed to haul 100 cars each holding 2 tons over a two-mile route. Tandem locomotives (two 13-ton units) were being offered by one manufacturer before 1906, however.

Use of gathering, relay and main-haulage units was an inevitable outgrowth of the increase in size of mines and the lengthening of hauls. Just when the first such system was installed is not known, but in 1915 the Sterling Coal Co., Salineville, Ohio, was employing the three types of units as a result of recommendations by E. B. McNichols, chief electrician. In that same year, the Berwind-White Coal Mining Co., Windber, Pa., purchased three 30-ton, six-wheeled Jeffrey haulage units, each with three 115-hp. motors, 33-in. wheels and a drawbar pull of 15,500 lb. at 8 m.p.h.

Weight of battery haulage units has, up to a certain point, kept pace with weight of trolley locomotives. As an example, the Phelps Dodge Corporation installed two 19½-ton combination machines with 88-cell 29-plate batteries at the No. 6 mine, Dawson, N. M., in 1924, for either individual or tandem service. Even larger units, however, are in service at the Coalwood and Caretta mines of the Carter Coal Co., in West Virginia. Equipment consists of 110-cell 39-plate batteries on 10-ton chassis, the whole weighing 23½ tons. Rated speed of the units is 4 m.p.h.

Available information fails to indicate just when the idea of reducing gathering-locomotive speed was adopted, but apparently it had been relatively little practiced by 1926, when the results of a test at the New Orient (Illinois) mine of the Chicago, Wilmington & Franklin Coal Co. were published. This test, conducted by A. E. Giles, electrical engineer, and W. E. McDougle, General Electric Co., on two 8-ton locomotives, one rated at 6.9 and the other at 3.5 m.p.h., showed that the average speed of the high-speed unit was 2.9 m.p.h., compared with 3 m.p.h. for the low-speed machine. Cars and tonnage gathered were practically the same for both units, but the low-speed machine consumed 37½ per cent less energy and ran up only one-half the 5-minute peak.

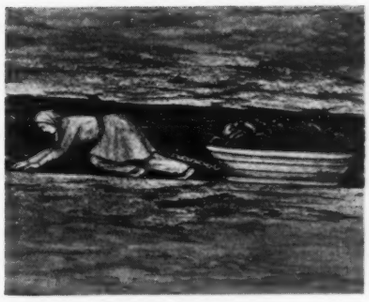
In 1928, the Berwind-White Coal Mining Co., Windber, Pa., purchased two 38-ton Baldwin-Westinghouse locomotives to pull 50 to 60 cars with a gross weight of 3.45 tons each over a 4-mile haul with an average grade of 2.37 and a maximum grade of 5.6 per cent. In the following year, the Consolidation Coal Co. installed at its No. 63 mine, Monongah, W. Va., two tandem locomotives, each consisting of two 20-ton Jeffrey locomotives permanently coupled together.

Up to March, 1935, the Monongah units had hauled approximately 3,500,000 tons with a maintenance cost of about ½c. per ton, about one-third the maintenance cost of the 10-ton locomotives previously used. Average one-way haul in March, 1935, was 2.7 miles, and the average grade against the loads was 1.21 per cent. Rated speed of the units—which together handle over 3,000 tons per shift in cars weighing 4,426 lb. and holding 4 tons—is 11.5 m.p.h. In late years a number of General Electric and Jeffrey tandem locomotives of 45 and 46 tons have been installed in western Pennsylvania mines of the Vesta Coal Co.

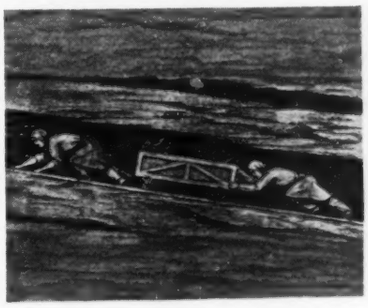
1911 Car Built Simply

The bituminous mine car of 1911, excluding minor modifications of design, was either the swinging or lifting endgate type constructed of wood on a skeleton of car irons. Through axles were general, and the wheels, of the plain cast-iron type with chilled tread, usually were fastened on with a cotterpin, although self-oiling, waste-packed, closed-hub and similar types were coming into use, along with the angle-bar truck and other means of maintaining axle alignment. Practically the same conditions prevailed at anthracite mines, except that car design, still standard today, was based on making the body a box with an outside wood frame. Car capacities generally ranged from 1½ to 2½ tons, although larger and smaller cars were used.

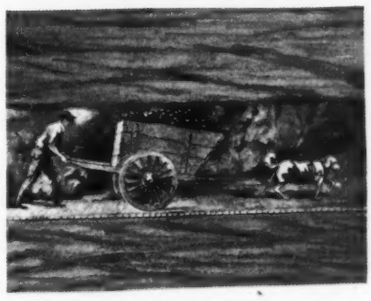
The precursors of modern practice, however, began to make headway even before 1911. Steel cars, for example, were being pioneered by Watt and others shortly after 1900, and on Jan. 20, 1903, twenty sets of Card straight-roller-bearing wheels were shipped to the Green Canon Coal Co., Aguilar, Colo. Primitive roller-bearing wheels apparently had been developed as far back as 1890, however. In 1908, Sanford-Day offered a straight-roller wheel, which was succeeded in 1913 by the "Whitney Wonder," which on test at the Toms Creek (Va.) mine of the Virginia Iron, Coal & Coke Co. showed power savings of 58 per cent over a solid-hub



Woman hauling "tub"



Women "putting" coal wagon



Dog haulage, U. S., before 1852

wheel. In 1914, tests of the Enterprise solid-roller wheel at the eastern Kentucky operation of the Elkhorn Mining Corporation showed power savings (power at 1½c. per kilowatt-hour) of ⅛c. and over-all savings of 1¼ to 1½c. per ton.

Straight roller bearings held the field until about 1910, when the Lobdell-Hyatt truck was brought out, the predecessor of a number of trucks with spiral roller bearings. In 1920, the Timken tapered roller bearing, handling both thrust and radial loads, was offered to the mining industry, to be followed several years later by the Tyson "cageless" tapered roller bearing. Ball bearings for car wheels were used to a limited extent fifteen or twenty years ago, but it is only in the past three years, marked by the Sanford-Day "Floater" ball-bearing wheel in 1933, that installation has been active.

Steel Wheels Increase

Cast- and wrought-steel wheels, used in increasing numbers in the past two or three years, also have their earlier prototypes. Wrought-steel wheels for railroad cars were pioneered in 1909, and in 1920, R. H. Morris, general manager, Gauley Mountain Coal Co., Ansted, W. Va., who had used cast units in Canada in 1912, installed a set of cast-steel wheels on a car at the Ansted mines. This first set remained in service until 1930. Companies lately embarking on the large-scale use of cast-steel wheels include the Old Ben Coal Corporation (1935); wrought steel, Pocahontas Fuel Co.

Steel for mine cars, as noted above, was first considered about 1900, but there is little evidence of material progress in the next ten years, although many operators had reached the point of making tests. In 1909, for example, D. T. Evans, Mt. Carbon Coal Co., Ltd., Carbon, W. Va., had a steel car built for test which, although higher in first cost, eventually proved more economical through savings in maintenance. Steel and roller bearings also figured in the first installation of 60 Sanford-Day bottom-dumping cars in 1916 at the Typo (Ky.) mine of the First Creek Coal Co.

One of the earliest users of steel cars embodying present-day features was the Lehigh Navigation Coal Co., Lansford, Pa., which, after several years of experimentation and the building of several test types, installed 175 new cars, built by the American Car & Foundry Co. from a design developed under the supervision of R. E. Hobart, then master mechanic, at the Coaldale colliery in February, 1913. In addition to all-steel construction, these cars featured ratchet brakes, spring-supported journal boxes and spring drawbars.

In 1919, in an attempt to better the structural-steel underframe, which averaged only three to four years, Lehigh Navigation installed its first cast-steel underframe—in effect a reproduction of the structural frame. In 1930, cast-steel underframes complete with flat bottom and pedestals were adopted, to be succeeded by a number of modifications designed to increase capacity or strength. One such, developed soon after 1930, was designed to accommodate the Miner Class "S" draft and buffing gear in a box-sectioned end sill to distribute shock over the entire frame. Late-type underframes installed by the company are fitted with the Miner T-3 friction-type draft and buffing gear, a small-scale reproduction of the railroad-type gear.

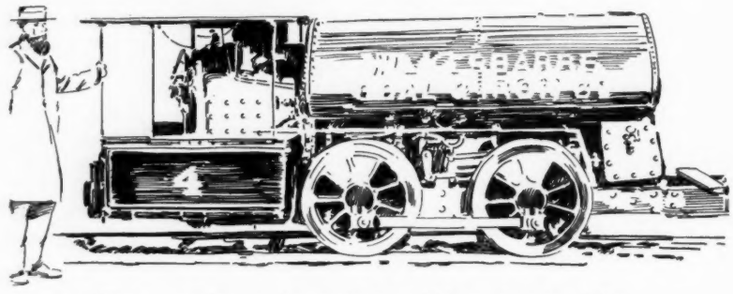
Alloy irons or steels ("Cop-R-Loy," "Mayari R," "Toncan," "Cor-Ten," "Armco," etc.) of either the corrosion-resisting or high-strength (lower car weight) types, a feature of developments in the past two or three years, also had their early adherents. In 1918, for example, the Ehrenfeld (Pa.) mine, Pennsylvania Coal & Coke Corporation, was using 700 Armco cars.

Spring draft and buffing gear, represented in the past five years by the Miner, Sanford-Day, Watt-Dalton, Bethlehem and other gears, also was early applied in the bituminous industry to reduce shock in moving trips, particularly where cars are large. In 1920, at its new shaft at Edwardsville, Ill., Donk Bros. Coal & Coke Co. installed 3-ton wooden mine cars with spring-type couplers on one end, giving both draft and buffing action.

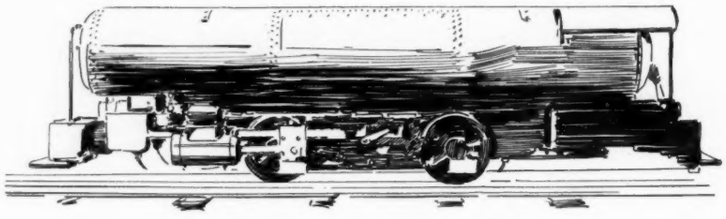
By 1924, 6- and 7-ton cars were coming into use in appreciable numbers in high coal, and designers were turning their attention to increasing the capacity of low-seam types. Such development still continues, even though numbers of low-type cars with capacities, in some instances, of 3 tons or more with heights of as low as 20 in. are in service. High capacity with limited height has been secured by eliminating part or all of the flare, increasing length and, within limits, width, and by using shrouds to permit raising the wheel up into the body. The same principles also are being incorporated in cars for higher coal, and types are now offered with a capacity of 6 tons or more with a height of 36 in.

Installation of a number of Commonwealth cast-steel endgate-type cars by the Jewell Ridge (Va.) Coal Corporation was a feature of developments in 1933. With a capacity of 4½ tons and a height of 30 in., weight of the cars is 4,200 lb. To date, the Jewell Ridge car represents the peak of the steel-casting art as applied to mine-car construction. Meanwhile, underframe installation continues, as evidenced by the purchase of a number of new cars with Duncan underframes for the St. Ellen mine, Perry Coal Co., O'Fallon, Ill., late in 1935.

Welding is another feature of



First steam locomotive underground in anthracite, 1870



First anthracite air motor, 1895

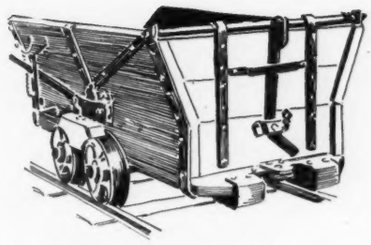
mine-car construction in the past five years. The Lehigh Navigation Coal Co. in 1931 installed a number of American Car & Foundry welded underframes. A year or two later, the Rochester & Pittsburgh Coal Co. commenced the installation of 1,000 A.C.F. all-welded steel cars in its central Pennsylvania mines.

Dumping cars for years was based on tipping them up on one end, first in the simple horn-type dump and later in the cross-over and other types. Rotary dumps, permitting the elimination of the end gate with its attendant difficulties, apparently were originated in the 90's. In a letter in the April 13, 1912, *Coal Age*, W. Harkes, general superintendent, Big Four Wilmington Coal Co., Coal City, Ill., stated that in 1897 he perfected a single-car rotary dump with back balance to return the car to position, using as a basis the double dump of Richard Ramsey, Braceville, Ill., in which the empty was returned to position by the next load. Three of the new dumps were installed at the No. 3 mine of the Big Four Wilmington company in 1898.

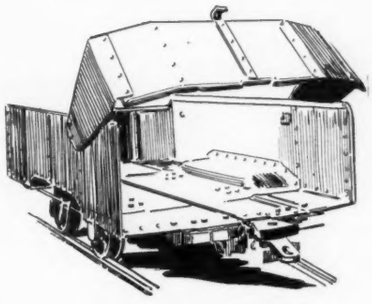
Uncoupling Eliminated

Elimination of uncoupling was the basis of the rotary dump developed by Erskine Ramsay, Birmingham, Ala., and first installed at the Smythe slope, Ore mine. Tennessee Coal, Iron & R.R. Co., between 1898 and 1900. To accomplish this, Mr. Ramsay proposed to dump an entire trip at a time or use a swivel coupling to permit dumping each car individually. In the Smythe slope installation, six cars were dumped at a time without uncoupling them from the hoisting rope. This practice of dumping entire trips also was followed in a number of subsequent installations, including: Lemont No. 2 mine, H. C. Frick Coke Co., Lemont Furnace, Pa., 1914, 18 cars at a time; Snowden Coal & Coke Co., Linn, Pa., 1920, 28 cars; Colonial Docks conveyor system, Frick, 1924, two dumps, each ,35 cars; Palmer Docks conveyor system, Frick, 30 cars.

The practice of dumping in trips was followed until 1908, when C. P. Perin adopted the swivel coupling in making the rotary-dump installation at the new Keokee (Va.) mine of the Keokee Consolidated Coke Co. (later Stonega Coke & Coal Co.). So-called "spiral" dumps, in which rails are arranged to turn the car, or the car body, over, go back to 1904 or earlier. In that year, such a unit was built by the Vulcan Iron Works for the Amsbry plant of the Pennsylvania Coal & Coke Corporation. Another such dump was proposed by Col. Edward O'Toole in 1922 in connection with an "endless" skip hoist, and in 1930 the Watt-Allen & Garcia dump was offered.



The bituminous car of 1911



Modern car of 1936

Still another type of continuous dumping equipment was installed at the Fairpoint No. 9 mine of the Hanna Coal Co., Fairpoint, Ohio, in 1931. Two Dongbeater dumping units running on tracks on each side of the haulage track raised the bodies of the 4½-ton Differential cars, equipped with Willison automatic couplers, to discharge the coal to one side or the other while the trip was in motion.

Along with faster transportation and increase in car and locomotive size has come an improvement in haulage roads. The earliest form of mine track consisted of wooden rails on ties of the same material. Rails generally were notched into the ties and fastened by wooden keys or wedges. This type of track persisted until comparatively recent times. At the mines of the Cannelton Coal & Coke Co., for example, haulage tracks between 1874 and 1890 consisted of 2x4s set on edge in notches in ties made of split posts. Wedges held the rails to gage. With mule haulage in the early days, steel rails weighing as little as 8 lb. per yard were used in many mines and 12- and 16-lb. rail was practically standard at the majority of operations.

The coming of the locomotive, however, materially changed this picture, as the increased weight forced adoption of heavier steel, with the result that most mines employing mechanical haulage went to 20- or 25-lb. rail in working places. Still further increases in mine-car size and the use of other heavy track-mounted equipment, such as cutting machines and loaders, resulted in still another jump in rail size, so that today, particularly at mechanized mines, rail weights of 35 and 40 lb. are not uncommon in working places.

Main-line haulage has been characterized by a parallel increase in rail size brought on by larger haulage locomotives, heavier trips and higher speeds, in addition to the benefits of stiffer construction and reduction in derailments. Twenty-five years ago, few mines used heavier than 40-lb. rail on main lines. By 1920, however, the Pennsylvania Coal & Coke Corporation, among others, had started to re-lay the main line at its Ehrenfeld (Pa.) No. 3 mine with 70-lb. steel.

At present, 60-, 70-, 80- and 90-lb. steel is employed at mines where the main-line haul is or will be any appreciable length and where the output is more than moderate. This steel weight usually is accompanied by 40-, 50- or 60-lb. rail on secondary haulways. Other present-day construction standards include establishment of uniform gradients, adequate drainage, proper subgrades, longer-radius curves, super-elevation, treated ties to reduce costly replacements; properly tamped mine-rock, "red-dog," crushed-rock, gravel and slag ballast, etc. In other words, the tendency is toward railroad standards in the construction of main-line and secondary tracks.

Welded Joints Adopted

To the above measures has been added in late years the practice of welding rail joints on main lines. Early in 1935, the Hanna Coal Co. inaugurated Thermit welding of rail joints at its Willow Grove (Ohio) No. 10 mine to reduce maintenance, facilitate operation of rolling stock and eliminate bonding. Copper equivalent conductivity is increased approximately 20 per cent. Angle bars are eliminated in the Hanna welding method, whereas under the welding system inaugurated at the New Monarch mine of the Consolidated Coal Co., Herrin, Ill., in 1933 (July, 1936, *Coal Age*, p. 275), the bars are retained. Labor and material cost of the welded joint is 68.2c.; of bonding the conventional joint, $1.004.

Another innovation in main-line

construction was the adoption of welded cross rails on each side of the rail joints at Wheeling division mines of the Valley Camp Coal Co. in 1934 (May, 1936, *Coal Age*, p. 171). The cross rails take the place of bonds, hold the rails to gage and prevent them from turning over, thus leaving to the spikes only the duty of holding the ties in place.

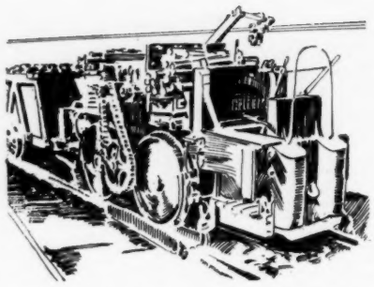
In the construction of room-entry and room tracks, steel ties have made rapid strides in the past 25 years. Investigation of the possibilities of steel ties probably goes back, however, to the 90s, and bolted steel-tie switches were offered by Weiner, Koppel and others around 1905. Apparently, though, steel ties did not begin to gain ground until after the invention of a channel tie by J. J. Ross, general superintendent, Hutchinson Coal Co., Fairmont, W. Va., in 1909, later distributed under the name Fairmont.

Steel Ties Spread

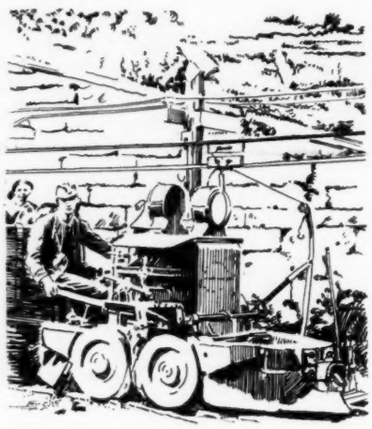
Easy application and savings in height made possible by this and other types, soon made with fixed and movable clips, have been major factors in their widespread use. In addition to what might be termed the standard tie, special types have been developed, such as the West Virginia-Cornett tie of 1935, designed to take the place of splice bars at joints. Steel ties also have found a field in the fabrication of portable track, both straight and curved, and in the construction of portable turnouts, particularly for room service. While steel-tie turnouts, such as the West Virginia (1923), originally were designed with special ties underlying the entire turnout, a number of operators lately have adopted the practice of using special ties only under the switches, with standard ties elsewhere.

In main-line service, steel ties have found their largest application as reinforcements for wooden ties; i.e., a steel tie is put between every third and fourth wood tie, for example, to assist in holding the rail in place and to gage. In a number of mines, however, steel ties are used alone, one of the earliest examples being the operations of the Old Ben Coal Corporation, Illinois. Mine No. 9 started using steel ties on main roads in 1913, followed by other installations at other company properties.

Construction of main haulage roads in mines also properly involves protection against falls of roof. At present, as in early times, timber is the mainstay in protective



First anthracite electric locomotive, 1887



First bituminous electric locomotive, 1888

programs, although steel in the form of shapes or rails has made progress over the years. Also, where timber is relied upon, more and more operators are turning to preservative treatment to prevent early decay and consequent frequent replacement with its attendant cost.

Probably the earliest use of steel timbering was at the shaft mine of the Spring Valley (Ill.) Coal Co., where about 400 ft. of openings on the bottom that had been burned out were timbered with 15-in. beams in 1896. In the following year, R. V. Norris installed the first lot of steel timber in the anthracite industry at the foot of Stearns shaft, Susquehanna Collieries Co. By 1907, according to some reports, there was about a mile of steel-timbered gangway in the anthracite region. In that year also, some authorities hold, steel timbering for mines really got its start with the rolling of H-sections designed for that service.

Installation of steel timbering to 1928 was based on three general methods: use of steel or wooden legs under steel beams; steel beams resting on concrete, brick or masonry walls; and steel beams set in hand-cut hitch holes. Hitch holes were adopted in many mines with bad conditions to get away from the possibility of having legs knocked out by derailments, not to mention failures from decay. However, cutting hitches by hand was expensive and the depth necessarily was limited. Consequently, the hitch drill was welcomed by many operators with difficult timbering problems.

Use of the Goodman turntable-type hitch drill was started in 1928 by the Valier (Ill.) Coal Co., which, in accordance with general practice in the Middle West, employed steel rails as crossbars. Each rail was set in holes, one on one side of the entry and one on the other. In that same year, the Binkley Mining Co. developed a hitch drill with a double-ended threadbar allowing both holes to be drilled from one set-up by reversing the direction of rotation. This machine was designed for use in the No. 8 mine, Clinton, Ind., and later was adopted by several other Indiana operators. Early practice in that State also was based on the use of holes for each crossbar, which obtained until about 1932, in which year the Dresser mine of Walter Bledsoe & Co., Terre Haute, went exclusively to the pin-and-stringer system, now almost universally employed with the hitch drill because of the ease with which crossbars can be placed and recovered.

Concrete Support Adopted

Another form of timbering used to a limited extent in mines is reinforced concrete. The arch form of roof support for permanent openings, particularly the steel arch widely used abroad, has met with little favor in the United States, although the principle has been employed in several installations of Schaefer lining in the anthracite region in late years, notably at the Powderly colliery of the Hudson Coal Co. Under this system, precast concrete shapes are laid up in the form of arches.

Roof protection by spraying the exposed surfaces with a mixture of cement and fine aggregate, commonly termed "guniting," has been adopted by a number of operations since the first trials were made at the Bruceton (Pa.) experimental mine of the U. S. Bureau of Mines in 1914 by L. M. Jones. By 1920, this method of protection had spread across the country to the Rocky Mountains. Still further progress has been made since that time.

In addition to track and cars—the most generally used form of transportation—conveyors comprise still another means of moving coal, even

though they usually are applied with the idea of improving the productivity of the man at the face and consequently generally are classed as mechanization aids. Two of the largest underground installations in the United States, however, were made solely with the transportation idea in mind. The first of these, the Colonial Docks system of the H. C. Frick Coke Co., went into operation in April, 1924, to serve the Colonial Nos. 1, 3 and 4 mines.

Length of the Colonial Docks installation, which included Imperial fabric and Goodrich and Goodyear rubber belts, Stephens-Adamson conveyor mountings and rolls with Alemite fittings, and General Electric motors, is 22,930 ft., made up of one 60-in. and nineteen 48-in. belts. Up to July 1, 1925, the system had handled an average of 10,500 tons per day. Installation of another system (15,398 ft. long) to move coal from the Filbert, Footedale, Buffington, Lambert, Ralph and Palmer mines to the Palmer Docks was started in 1926. Both receive coal from mine cars, whereas the several conveyor systems installed in the past two years carry coal away from mechanical loaders (p. 404).

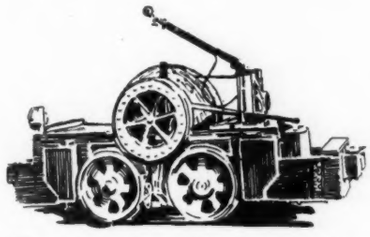
Electric Hoists Increase

Hoisting developments in the past 25 years have been marked largely by an increase in electrified types, although steam hoists still are common, as well as an increase in size to handle the larger mine cars and tonnages of recent years. Hoisting from greater depths also has played a part in the increase in equipment size, particularly in the anthracite region. Platform-type cages still are standard in the hard-coal fields and self-dumping cages at bituminous mines.

Hoisting individual cars, however, is subject to certain limitations of car size and hoisting speed, and, although these have been broadened in late years, they still apply. Consequently, an increasing number of bituminous operators have turned to skips to increase the quantity of coal per hoist and thus secure higher output with reduced hoisting speed. Attempts to attain the same objective with cages was reflected in several early installations of multiple-deck cages, including a four-deck cage at at least one central Pennsylvania operation, as well as two-car cages of the platform and self-dumping types. The latter, for example, were installed by the Monroe Coal Mining Co., Revloc, Pa., and the Pittsburgh Terminal Coal Corporation, Coverdale, Pa., in 1922 and earlier.

Possibly the first skip installation was at the Sherard (Ill.) mine, Rock Island Coal Co., in 1894, presaging a number of installations in Illinois, Indiana and other regions since. The record for a daily hoist is held by a skip-equipped mine—New Orient, Chicago, Wilmington & Franklin Coal Co., West Frankfort, Ill.—which raised a total of 15,174.35 tons, including approximately 2,500 tons from the auxiliary shaft, on March 22, 1928. On Nov. 3, 1926, less than two years after full-scale operation was started, 13,563 tons, or 1,175 skip loads, was hoisted. The New Orient installation, the largest in the bituminous industry, consists of a Nordberg cylindro-conical drum driven by two 2,000-hp. Westinghouse motors, one on each end of the shaft, with Ilgner-Ward Leonard control. Hoisting distance is 607 ft.

Skip-hoisting necessarily means dumping underground, and consequently the solid-end car with the rotary dump was early adopted and now is standard for this service. And although skips can be adapted to handling men and materials, general practice has been to install auxiliary shafts for this purpose. An outgrowth of these factors was the development of the overturning cage by the Allen & Garcia Co. An early installation of the overturning cage, which permits the use of solid-end cars with self-dumping equipment, was at the Donk Bros. mine noted above, where they were employed to handle the mine output through the auxiliary shaft from about 1920 until late in 1923, when the skips were installed in the main shaft.



"Wampus" cable-reel locomotive, about 1899

Modern haulage locomotive

Although most overturning cages have been installed in connection with skip-hoisting, they later were applied exclusively at a number of operations such as the Dresser mine of Walter Bledsoe & Co., Terre Haute, Ind. (1926), and—the latest—the new Talleydale shaft of the Snow Hill Coal Corporation, Terre Haute.

Early operation of platform and self-dumping equipment was based on manual caging until, apparently, about 1911. Development of automatic equipment was started by the Mining Safety Devices Co. in 1910, and by 1918 installation had become fairly active. In 1920, the Nolan automatic cager was first installed by the Coal Ridge Mining Co., Linton, Ind. About 1900, the Holmes car lift, one of the several methods of eliminating car hauls or hoists for returning empty cars to the inbound tracks, was being actively promoted. Anthracite practice in late years has been characterized by a growing use of the transfer truck, employed either for distributing cars from one or more loaded tracks to the various cages or for returning empties directly to the inbound track.

Conveyors Find Favor

At a number of slope mines, conveyors have been favored over the hoist in late years. And as a by-product of improvements in conveying equipment, slopes have been adopted at several operations where shafts would have been put down in earlier days. A number of steel-apron slope conveyors were in operation prior to 1920, and at about that time tests of a slope conveyor and shaft hoist at Dehue, W. Va., showed that with the same depth (90 ft.) and the same capacity (2,000 tons per day), energy consumption of the hoist was 0.31 kw.-hr. per ton, as compared with 0.23 kw.-hr. for the slope conveyor. The peak established by the latter was two-thirds less than the hoist peak.

Application of belts to surface work started to gain ground about 1910, although it was some years before they were adopted for slope use, as, for instance, at the Lewis mine of the Hudson Coal Co., Clarksburg, W. Va., where a 247-ft. belt

on an 18-deg. pitch went into operation some time before 1923. At that time also, a 430-ft. steel-apron conveyor on a 30-deg. slope was in operation at the Kinloch mine in western Pennsylvania, handling 3,400 tons per day. And in 1923 the DeBardeleben Coal Corporation installed a 485-ft. belt on a pitch of 19 deg. 53 min. at its Townley (Ala.) mine. By 1930, improvements in belts and methods of applying them had proceeded to the point where an installation with a capacity of 1,000 tons per hour, 900 ft. long between centers on a pitch of 18 deg., was made at the Wildwood (Pa.) mine of the Butler Consolidated Coal Co.

Concentration of transportation control in the hands of a central authority, commonly termed dispatching, was a natural outgrowth of increase in individual mine output, longer hauls and the heightening tendency toward the separation of the transportation cycle into two or three stages. No data are available to show where dispatching was first adopted, but it is evident that its general application paralleled the use of the mine telephone. By 1925, dispatching had become common enough to warrant frequent mention in the technical press and by 1927 was stated to be the general practice in southern Illinois.

The increasing complexity of transportation systems also brought into use various forms of signaling equipment to prevent interference between and accidents to transportation equipment. When such systems were first employed is difficult to determine, but, in simple form, they probably antedate 1900. C. J. Fuetter, division maintenance superintendent, Consolidation Coal Co., Van Lear, Ky., referred to a mine signal system, apparently manually operated, in 1913.

In November, 1922, Consolidation installed the Canton automatic signal and flagger at Jenkins, Ky., followed, in December, 1923, by an installation at Putney, W. Va., by the Campbells Creek Coal Co. The year 1927 was marked by a sharp increase in number of systems installed, and in that year Banning No. 1 mine, Pittsburgh Coal Co., selected the Nachod SUD relay system developed primarily for railway service. The Fordson Coal Co., between 1929 and 1932 installed the Nachod type in three Kentucky and one West Virginia mines.

An automatic switch thrower to facilitate trip movement was offered by the American Mine Door Co. in 1923. In 1925, the Valier (Ill.) Coal Co. installed signal systems and solenoid-type semi-automatic switch throwers which permitted the elimination of two main-line and four gathering locomotives without affecting output. Cheatham switch throwers were included in the Fordson program. Still more widespread use of signal systems and switch-throwing equipment has characterized developments in the past five years.

SCIENTIFIC MANAGEMENT AND THE COAL INDUSTRY

By JEROME C. WHITE
Assistant Production Manager
Pittsburgh Coal Co.
Pittsburgh, Pa.

TWENTY-FIVE years ago the coal industry looked upon scientific management as a fad. During the intervening years this industry continued to regard it with skepticism, as it did many so-called efficiency systems that paraded throughout industry from 1910 until about 1920. Scientific management in its early days became the victim of its overenthusiastic friends by reason of numerous misapplications and much misinformation. During the World War, with its tremendous problems of organization and production, scientific management was stripped of its many nonessentials and interesting but useless appendages and then emerged as a real factor in the management of industry. The post-war years saw a further trimming of the frills.

True scientific management never was an efficiency system or a combination of systems. The early mistakes were made because the details of a successful application were mistaken for the principles. As a matter of fact, scientific management is entitled to the use of the term "scientific" only when it makes use of the methods of science. These methods are: to observe, record and analyze. Upon these as a foundation management applies the results to plan, schedule, dispatch and control.

Therefore, the fundamental characteristic of scientific management is control—based upon facts—by the use of scientifically determined standards. The present field of scientific management is comprehensive and includes the whole field of business, with particular emphasis upon production. The use of engineering in management contemplates the basing of decisions upon facts and not upon opinions.

The entire field of management cannot be reduced to a mathematical exactness. Management will, to some extent, remain an art rather than an exact science. However, the application of scientific principles of detailed and accurate observation, or research into and analysis of, operations and conditions will obviate many of the losses due to guesswork. In the light of more recent results, particularly within the coal industry, scientific management deserves a new appraisal of its potential value. The coal mining industry as it progresses in production efficiency, particularly in mechanization, faces the same problems that confronted other industries: that of getting material to and away from the machine.

Extensive uses of the methods of scientific management have been made by the coal industry. In my opinion the program is well balanced. Of course, the production departments are interested in producing more coal and cleaner coal and in doing it at lower cost. The mechanization of production will increase potential capacity. Research in the field of coal utilization seeks a wider market, and wider markets provide an outlet for production. A few examples will illustrate.

The growth of the byproduct industry in the past ten years has been enormous. The development of the small automatic stoker for the home with the development of a satisfactory sized coal to be used in it has

saved many millions of tons of coal to the industry. Research into the treatment and preparation of coal for domestic uses will save more millions of tons to our industry.

When sales departments make an engineering study of the technical requirements of their customers and when production departments cooperate to meet these needs, a doubting customer is saved to the industry. So long as scientific methods are being used to save our markets, and research is being carried on to widen the uses of coal by finding new applications, even to changing the accepted forms in which coal has been sold, I believe the program of the coal industry is well balanced. Intensive production methods, though inevitable, need not, and will not, throw the whole industry out of balance.

When the coal industry spends so much money and effort to improve its product to save its markets, and encourages and finances scientific research to determine new forms and new uses to widen its markets, then scientific management in production has no apologies to make for its progress. There are many mines that are scientifically managed without any banners to label this or that mine as being operated under a "scientific management system." Operations are planned, scheduled, dispatched, and controlled.

Time study is no longer a "speed-up" threat. In fact, the effective time-study observer should be critical toward the inefficiencies of management. Time study has passed from the mere use of a watch to see how long it took to do work to its more proper place of job analysis: to determine the best way to do work. It seeks to eliminate waste. Waste and inefficiency benefit no one; least of all workmen. When the best way to do a job has been determined it usually is the easiest way. Increased productivity per man or per unit of equipment does not mean speed up in the sense of working harder or faster. An efficient workman, or group of workmen, or mine organization does not necessarily mean that they have been "speeded up"; rather, that they have been taught the easiest way to do work and the best equipment has been provided for them with which to do the work.

If we examine a transportation system that has been increased in productivity per unit of equipment we will not find that it has been made so because men work faster and less safely. But we will find that the locomotives are faster and safer because a high-class roadbed of heavy rail and heavy ties well ballasted and graded have been provided. Trip movements are controlled by a dispatcher and his telephone system and, in many cases, are protected by automatic block signals with electrically operated track switches thrown by the operator from his cab.

By recognition of the principles of scientific management this type of management has been increasingly in evidence during the past ten years. The exact technique may differ among a number of companies. But these principles are discernible: there has been a plan; the plans are carried out by scheduling and dispatching; operations are controlled. The details may vary, but the principles are the same.

I have observed all the many devices of scientific management become increasingly useful. Time study has been used to improve operations and as a basis of planning work; job standards as to time, method, quality and costs are set. Cost and production are controlled by comparing actual results against predetermined standards. Budgetary control of operations is a vital part of management technique.

JEROME C. WHITE

Brings to his discussion of scientific management both long study and practical experience. After being graduated from college, he worked in mines in Colorado and British Columbia and later was associated with the Rochester & Pittsburgh Coal & Iron Co., Penker Mining Co. and Lindsey Coal Mining Co. He interrupted his mining career first to serve in the World War and later, in 1924, to attend the Harvard Graduate School of Business Administration. After leaving Cambridge, he spent some time with the Davis Coal & Coke Co. In 1926, he joined the editorial staff of Coal Age and resigned the following year to go with the Pittsburgh Coal Co.

A description of budgetary control of operations would embrace practically the whole field of production management. I will attempt a brief outline. The sales department first makes a survey of its markets and then determines the probable quantity of coal it will sell and at what price for the coming year. This information is then given to the production department, which estimates production costs; projects the required development; specifies the required capital expenditures for new equipment and for maintenance and replacement; plans development in new methods or equipment that offer promise of lowering costs; furnishes each mine superintendent and his staff his budget and outlines the specific job for each department head. The comptroller, or other appointed executive officer, consolidates the several budgets into a master budget by which the course of the company is charted for a year ahead. From this general statement of principles will develop many variations as to technique.

The coal industry has applied the well-tried principles of successful modern manufacturing to the production and sale of coal. So long as scientific studies are made to increase the usefulness of coal the industry is justified in promoting the scientific production of coal.

As the fundamentals of scientific management become better known, increasing use will be made of this type of management. There is an increasing interest in the types of management used in other industries and the principles are becoming better understood. The groundwork for a wider application of scientific management in the coal industry has been laid and the future will see an increasing adoption of its basic principles.

Recognize the principles and the details will take care of themselves. The initial steps in the establishment of scientific management are to observe, record and analyze. From the information thus obtained the work is planned, scheduled, dispatched and controlled. The movement has been started, and as it becomes better understood by being tested under actual operating conditions the progress of scientific management will be more rapid and the industry should greatly benefit.

PREPARATION

COAL preparation, in one form or another, is as old as coal production. Doubtless, too, the same underlying principle — satisfaction of the consumer's needs or desires, with the hope of consequent benefit to the producer —applied then as well as now. Operation of this motive in the United States bituminous industry in the last 25 years has been reflected in a major increase in screening, supplemented in recent years by special equipment for making mixtures; a material increase in mechanical cleaning attended by the adoption of new types of cleaners almost entirely supplanting those originally used; and the introduction of certain auxiliary beneficiation methods, such as dedusting and dustless treatment.

Examples selected at random offer a partial measure of the changes in the past 25 years. In Illinois, where multiple sizing was comparatively well established at the time of *Coal Age's* birth in 1911, the Saline County Coal Co., Harrisburg, started building a new mining plant in 1910. With an hourly capacity of 500 tons and considered well abreast of the times, the preparation plant included a roller-mounted inclined shaker screen with flygates for making lump, egg, nut, screenings and combinations, all chute loaded, with mine-run as an additional size loaded directly from the dump hopper.

In 1936, the Sahara Coal Co., Harrisburg, began a tipple and cleaning plant with a capacity of 825 tons per hour and equipped with automatic washers for minus 6-in. coal; drying equipment for minus 5/16-in. coal; sizing equipment for eight primary sizes, with selective mixing of any sizes; and box-car loaders for all sizes or mixtures; and special primary and secondary crushing equipment.

Early methods of conveying, screening and jigging ores (Agricola, 1556).

Some 1911 Usages Modern

Other fields offered in 1911 some examples of hand-picking and screening practice comparing favorably with present-day standards, although using somewhat different equipment. In the Fairmont field of northern West Virginia, the Four States Coal Co. plant included four loading tracks, shaker screens for separating the mine-run into lump and smaller, two scraper-type "picking bands," on which the pickers walked while working, two apron-type loading booms for lump and/or mine-run, two revolving screens for separating the undersize from the main shakers into nut and slack, and an auxiliary revolving screen for separating the undersize from the main revolving screens into pea and also dust, sent to the boiler plant. Chutes permitted loading any desired size mixture.

In contrast, the Consolidation Coal Co. now operates at its No. 63 mine, in the Fairmont field, a new plant with a shaker screen for making lump, egg and nut, which are picked and loaded over apron-type picking table-loading booms, vibrating screens for separating the undersize from the main shaker into pea and slack, a crusher for breaking down lump and egg, when desired, a scraper-type mixing conveyor and two slack-storage bins. Seven loading points are provided and, with the bins, five sizes can be loaded simultaneously.

Despite the relatively modern tipples in use in 1911, the bulk of the bituminous product outside Illinois and Indiana received either no sizing or only simple separation into two or more sizes over stationary screens. This latter system was inherited from earlier days when slack, except in coking coals, was considered a waste product and was left in the mine or screened out on the surface on a stationary screen, usually of the bar type, and wasted. Present-day screening standards grew largely out of market competition, changes in consumer requirements and revisions in methods of paying the miners. Sizing, for example, and particularly separate rescreening of minus 2-in. coal, largely confined to that State, was one of the means used by Illinois to combat Eastern high-volatile coals in Mid-Western markets. Also, the sized product resembled anthracite, then a strong factor in these markets.

Sizing of coals from the utilization standpoint began to assume importance late in the last century with increasing appreciation of the benefits of sized coal in promoting combustion and development of equipment for using the fine sizes in steam raising. In addition, in some producing States (Illinois, 1897; Arkansas, 1905; Ohio, 1914; etc.), the passage of legislation establishing the gross-weight method of paying the miner stimulated operator interest in disposal of the smaller sizes.

Screening Was Simple

It seems apparent, however, that despite these developments, rather simple screening prevailed in many bituminous regions well into the decade 1910-20. In Ohio, western Pennsylvania and the "bituminous district of Indiana," for example, screening was largely predicated before 1914-16 on a union agreement containing the following: "Screens . . . shall be uniform in size, 6 ft. wide by 12 ft. long, built of flat or Akron-shaped bar of not less than $\frac{5}{8}$-in. surface with $1\frac{1}{4}$ in. between bars, free from obstructions, and that such screen will rest upon a sufficient number of bearings to hold the bars in proper position." As late as 1914, H. C. Adams proposed that operators in the East, South and Middle West abandon the sizes then made and re-

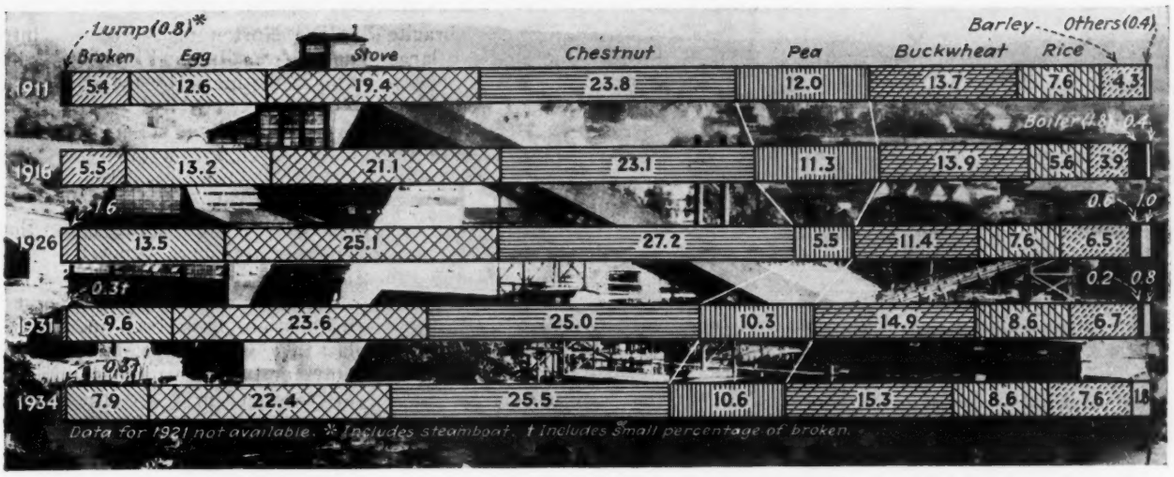


Fig. 1—Changes in size percentages in anthracite shipments, excluding washery and dredge output.

turn to the old standard of 1¼-in. lump and screenings.

Definite percentages for earlier years cannot be given, owing to a lack of size studies, but in 1927, according to the U. S. Bureau of Mines, screening had increased to a point where 29.3 per cent of all shipments was prepared sizes, 20.5 per cent was slack or screenings, and 50.2 per cent was mine-run. In 1930, a *Coal Age* survey showed, the averages for 49 producing regions were: mine-run and resultants, 38.3 per cent; prepared sizes, 35.3 per cent; screenings and other residues, 26.4 per cent. In the same fields, the 1927 Bureau of Mines averages were: mine-run, 48.3 per cent; prepared sizes, 30.7 per cent; residues, 21 per cent.

Sizing Established Early

In the anthracite region, on the other hand, the principle of multiple sizing was firmly established 50 years ago, and 25 years ago mechanical cleaning was well on its way to universal application. Number and designation of sizes in 1936 are but little different from those in 1911 (Table I), but many changes were made in the intervening years followed by gradual acceptance of the present standards. In that period also, the smaller sizes, including No. 4 buckwheat, practically unknown in 1911, have come more to the fore (Fig. 1), both in quantity and quality, with the development of equipment and methods for utilizing them, and standards for oversize, undersize and impurities in all sizes have been raised. Cleaning equipment also has undergone marked revisions in many cases, with increased efficiency, simplified plant design and reduced operating labor as the goals.

The Buck Mountain breaker of the Lehigh Valley Coal Co., erected near Mahanoy City, Pa., early in 1912, furnished an example of the latest thought on hard-coal preparation in the Southern field 25 years ago. In this breaker, operated by a crew of 36 (many earlier breakers had staffs of well over 100, mostly slate pickers) and with a daily capacity of 1,500 to 1,800 tons, egg, stove, chestnut, pea and buckwheat were washed in twenty jigs. Rice and barley was prepared by screening only, and the resultant fine material was run to waste. Evidencing even then changing styles in sizing, provision was made for breaking all coal to egg and smaller. Prior to breaking, lump and steamboat were hand-picked and broken was run over a mechanical picker. Cleaned coal from the jigs passed over degradation screens and was inspected by pickers, and provision was made for repreparation of condemned coal. A belt conveyor with loading-boom head, preceded by degradation screens in the discharge chutes from the pockets, was employed for loading all sizes.

At Gowen colliery, a few miles away from the old Buck Mountain breaker site, the Buck Mountain Coal Co. installed in 1933 a new steel breaker with a capacity of 1,600 tons of raw feed in eight hours. Two cleaning units wash all sizes from egg to No. 4 buckwheat, inclusive. Egg to pea inclusive are loaded over a belt-type boom. Lump and steamboat are hand-picked and rolls are provided for breaking all coal to

Table I—Comparative Anthracite Preparation Standards

	Lehigh Navigation, 1911		Anthracite Institute, 1936	
	Screen Mesh, Inches Diameter			
Sizing:	Through	Over	Through	Over
Broken	4 1/2	3 1/4	4 3/8	3 1/4
Egg	3 1/4	2 5/16	3 1/4	2 7/16
Stove	2 5/16	1 5/8	2 7/16	1 5/8
Chestnut	1 5/8	7/8	1 5/8	1 3/16
Pea	7/8	9/16	1 3/16	9/16
Buckwheat	9/16	5/16	9/16	5/16
Rice	5/16	3/16	5/16	3/16
Barley	3/16	3/32	3/16	3/32

	Maximum Per Cent			
Oversize and Undersize:	Oversize	Undersize	Oversize	Undersize
Broken	..	..	5	15
Egg	5	20	5	15
Stove	5	20	5	15
Chestnut	5	15	5	15
Pea	5	20	10	15
Buckwheat	10	20	10	15
Rice	10	20	10	15
Barley	10	25	10	20

	Maximum Per Cent				
Impurities:	Slate	Bone	Slate	Bone	Ash
Broken	20*	20*	1 1/2	2	..
Egg	2	2	1 1/2	2	..
Stove	4	3	2	3	..
Chestnut	5	5	3	4	..
Pea	8	..	5	5	..
Buckwheat	10	..	...	..	15
Rice	..	..	...	..	15
Barley	..	..	...	..	15

* Pieces on top of a car.

egg and smaller, for crushing flat nut and stove prior to repreparation and for breaking down and recirculating washed egg, when desired. Lip screens in the chutes from the loading pockets remove degradation from egg to buckwheat, inclusive. Condemned coal is returned to the plant for repreparation. Gowen breaker is operated by a force of twelve men.

In the Northern anthracite field, however, where pitches are light and consequently less refuse is loaded with the coal, dry preparation was almost universal in 1911, and was adopted for the Loomis breaker, Glen Alden Coal Co., started in 1913 and considered to be abreast or ahead of practice in that day. With a capacity variously reported at 7,500 to 9,000 tons per day, this breaker was first equipped with Norman and Devers pickers and spiral separators. In common with all other plants in the field, however, it later was converted to wet washing and now, as a result of a final improvement program in 1932, employs three washing units for the following size groups: egg to buckwheat, inclusive; rice to No. 4, inclusive; and silt. Capacity is now 825 tons per hour.

Both screening and cleaning, the major methods of improving the quality of coal, go back centuries, and both owe much to metal-mining developments. Agricola (1556) described the use of both hand screens and washing equipment. Modern coal-preparation methods, some authorities hold, began to develop in the 70s and 80s in France and Germany and during the early 90s in England. Table II summarizes the major screening and cleaning developments overseas before and after this time.

Anthracite Starts Work

Coal preparation in the United States got its start in the anthracite region. After 1808, when Judge Fell, of Wilkes-Barre, demonstrated the practicability of burning anthracite in an open grate, preparation consisted of picking out the largest lumps in the mine. This system continued until 1830, when the first preparation scaffold was built on the surface. Even then, only lumps were brought to the surface, and were placed on a perforated plate and broken down to commercial sizes by sledges. About this time, the hand rake, with teeth giving an opening of about 1¾ in., was introduced in the mines, where it was generally used until about 1850 and possibly as late as about 1869, when it was found possible to utilize pea.

Possibly the first anthracite breaker, the forerunner of the large and expensive structures of the present day, was erected by Gideon Bast at Wolff Creek, near Minersville, in 1844. This breaker incorporated the first power-driven crusher rolls, patented by Joseph Batten, Philadelphia, in the same year. Although materials and details have changed, Batten's principle still applies in roll design. Bast also installed revolving screens for sizing and drove both the rolls and screens with a steam engine. Incidentally, he was the first to substitute steam for hand power in turning screens.

Revolving Screens Used

By 1860, revolving screens were widely used in anthracite breakers. Shaker-screen development started about 1890, motivated by a desire for equipment that would handle large quantities of material with higher efficiencies and less breakage. One of the first was the Anthony shaker, which was hung by rods suspended from ball-and-socket joints and connected to the screen frame by pins. The Anthony shaker, however, was preceded by a high-speed roller-supported machine and by the Coxe gyratory screen. In succeeding years, the flexible-arm, or Parrish-type, shaker was developed, operating at a relatively low inclination and particularly adapted to screening fine sizes where loads are not excessive. This screen later was widely adopted in the bituminous fields for fine sizes and rescreening.

Breaking, or crushing, by means of rolls has been an integral part of the anthracite preparation cycle since the early days, but in the bituminous industry crushing has never, with a few exceptions, been a major element in preparation, although figuring largely in utilization in a number of consuming industries. An early adaptation of crushing or breaking was the freeing of clean coal from impurities, in which the Bradford breaker, patented in 1873, designed for anthracite and first used in the bituminous industry in 1891, has been a leader. Conventional types of crushers also have been adopted, particularly in late years and in mechanical cleaning plants, for the same purpose.

Another early application of crushing, or breaking, still in effect in many plants, was the reduction of lump size, not to destroy the lump but to make it easier for the customer to manage. One of the latest types of equipment for this particular purpose, both with and without integral rescreen to remove fines, is the Norton pick breaker (introduced from England in 1932), which breaks the lumps by the piercing action of pointed picks. So-called "needle" crushers (Sauerman, etc.) were developed before 1920, however. Pickhammers also are used in some tipples.

Aside from these applications, however, crushers generally play a secondary rôle in bituminous preparation, although a great number of installations have been made in the last five years or more—nearly all only for breaking down coarse sizes at times when no market demand exists for these grades. At only a few operations is the anthracite practice of breaking down all large coal followed, one being the new Talleydale plant, Snow Hill Coal Corporation, Terre Haute, Ind., where present practice is based on the shipment of only egg and smaller.

Only Lump Was Mined

Like anthracite, bituminous preparation was first based on mining lump only, after which came the fork, rake and pan, hand screen and "grill," or wooden bar screen, all having the same objective—elimination of the fines, at that time, except for coking coal, unsalable. Rakes and pans and similar equipment were almost out of Illinois by 1884, although some persisted until the strike of 1897, staged primarily to secure the gross-weight method of paying miners. Stationary bar or perforated screens, usually the former, were early adopted to eliminate fines on the surface, and were widely used until well into the present century. A few still are employed.

The first bituminous shaker screen —single-deck—was installed in 1890 at Slope No. 4, Pratt mines, Tennessee Coal, Iron & R.R. Co., Alabama, by Erskine Ramsay, Birmingham. It was succeeded by a double-deck balanced unit. In Illinois, installation of a shaker screen to replace a bar screen at the Gillespie breaker, Consolidated Coal Co., was reported in 1890. Six years before, a reciprocating screen, probably of the bar type, for "washing" slack was reported in the Wilmington field of Illinois.

Breakage militated against general adoption of revolving screens for sizing large bituminous coal, although many mines, as the demand for smaller coal widened and the gross-weight method of payment spread, adopted them for the finer sizes, employing shaker screens for large coal. In Illinois, revolving screens were employed at several

operations before 1884, and after the gross-weight decision were widely used, with shaker screens for coarse coal, until about 1910, when the flexible-arm shaker was introduced from the anthracite region for fine sizing. Although not general, revolving screens persisted in some fields for several years after 1910, however.

Early shakers were operated inclined and with a simple reciprocatory motion. These principles still govern most installations. Shortly before 1915, however, a number of variations, including the Krehbiel horizontal screen and the "Anti-gravity" screen—inclined upward from the feed to the discharge end and with provisions for imparting a pulsating movement to the screen surface—came into use. In 1912, the Marcus screen, a combination screening and picking unit with horizontal deck, still widely used, was introduced in the bituminous field from England. A differentially accelerated motion moves the coal forward. Another screen with horizontal deck and similar motion was the Dodge-Zimmer. The Peterson pendulum, or short suspension, shaker made its appearance in 1916. The suspension and drive impart a rocking motion to the screen which throws the coal up and forward.

Various methods of absorbing or neutralizing vibration, swaying and shock have been used with shaker screens. In 1933, at the Consolidation Coal Co. tipple described above, the screen drive (motor, V-belt connection and crankshaft) was mounted on a platform suspended from the tipple structure and free to swing about 1 in. either way. Developed by J. W. Murry, engineer, construction department, the suspension lightened and simplified the structure. In an earlier screen, developed by C. L. Miller, Scottdale, Pa., about 1922, the entire unit, of the horizontal type, including drive, was mounted on long spring pedestals on separate foundations.

Another sizing unit which had its inception 25 or more years ago is the vibrating screen, although it was preceded by even earlier versions of the vibrating principle. Original vibrators, reflecting their growing importance, were designed primarily for fine sizes, but widening application in late years has resulted in exclusive use in several tipples: Syracuse Mining Co., Pomeroy, Ohio, 1931, and the Beaver Run Coal Co., Beaverdale, Pa., and Hastings (Pa.) Fuel Co., 1932. Vibrating screens began to hit their stride around 1925-26, and now are widely used for small sizes and rescreening, removing dust from fine coal, particularly stoker coal, certain dewatering applications and several other screening applications, where their small size, relatively low cost and resistance to blinding favor their use.

Tappet screens for fine coal were one of the earliest embodying the vibratory principle. Another early screen, with a number of modern forms, was the pulsating unit, in which the screen frame was given a series of rapids lifts, or pulsations. Bumping, or knocker, screens, in which the lower end is lifted and dropped on a bumping block, also were early favorites for coal under 3 in. Modern vibrating screens generally fall into two classes, depending on whether the screen cloth only or the entire screen frame is vibrated. Original models fell largely into the first class and the cloth was vibrated mechanically, as electric drives were not available until about 1920, when two types of electric drives were offered. One, from the copper industry, involved a motor with unbalanced weights, and the other, first installed on coal at Steelton, Pa., in 1919, uses magnets.

Although pulsating screens were one of the earliest types, impact types antedated them in general use. In most of the new vibrators offered in the past five or ten years, however, the entire frame is vibrated, generally with a simple forward and up and backward and down, or cir-

Table II—Major Steps in Development of Overseas Screening and Mechanical-Cleaning Practice

Screening

1556—Agricola describes use of hand screens.

1740—"The mischievous practice of screening coals was first introduced at Willington colliery by Mr. William Brown."

1833—Bar screen with provisions for quickly varying openings patented by Hall, England.

1851—Berard, about this time, uses flat suspended bumping screen for pre-sizing jig feed.

1867—Cylindrical screen, patented by Walker in 1854, used for coal screening in England.

1870–1880—Movable screens, developed for ore-dressing over 100 years earlier, adopted by German coal mines.

1872—Briart's moving-grate screen with screening and conveying action installed at Belgian colliery.

1895—English "Vibrometer" gyrating screen introduced about this time.

Mechanical Cleaning

1556—Agricola describes early hand jigs and trough washers for ore-dressing.

1830—Hand-operated movable-sieve jig applied to coal cleaning in Saxony about this time.

1840—Hand-operated fixed-sieve jig with plunger and washing compartments used near Dresden about this time.

1841—Trough washers appear in France and Belgium about this time.

1848—Continuous jig washer developed by Berard, a Frenchman, who also adopts pre-screening of the feed, a practice that still persists, although reduced in importance.

1855—Mackworth, believed to be the first upward-current coal washer, invented.

1867—Rittinger, Austrian mining engineer, publishes his classical work on ore-dressing and in deriving laws governing fall of particles in still water, concludes that close sizing is necessary in jigging. Although later proved too sweeping, this conclusion greatly influenced jigging for many years.

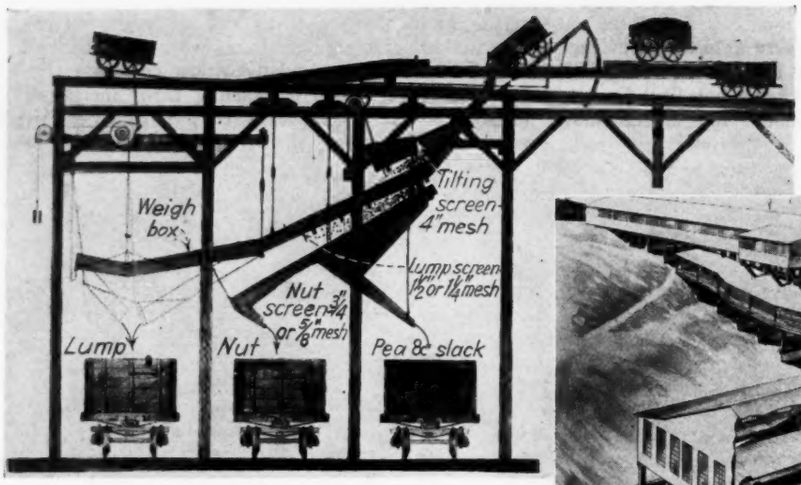
1867—Feldspar washer erected in Lower Silesia, employing Luhrig jigs patterned after the Hartz feldspar jig previously used for ore-dressing. The Luhrig jig, which also included the "flow" principle, in which the coal moved through washer parallel to the dividing wall between washing and plunger compartments, instead of at right angles (the "cross" method), as in previous jigs, solved many of the difficulties previously encountered in washing fine coal.

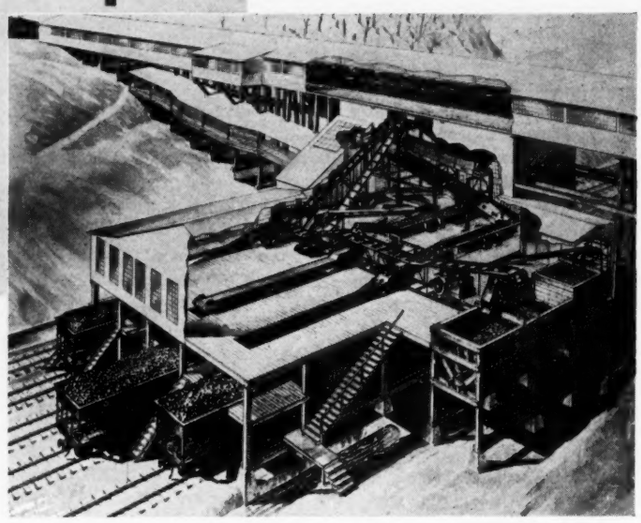
1882—Fritz Baum, Herne, Westphalia, develops jig using compressed air to impart pulsations to the water. The positive suction strike was eliminated and the jigging cycle momentarily provided a relatively still washing bed at the end of the pulsion stroke, thus allowing settling, in the initial stages of fall, by density differences only, independently of particle size. Close pre-sizing and the "cross" method were followed.

1885—Robinson upward-current washer, one of the early types in the United States, installed at the collieries of Messrs. Bolckow, Vaughan, England about this time.

1901—Baum erects washer using the flow principle previously employed by Luhrig on fine coal only and proves that a wide range of sizes can be handled in a single wash box without pre-sizing, his findings paving the way for a reduction of approximately two-thirds in sieve area for efficient washing, a material increase in washing capacity and a substantial decrease in washery costs. Rittinger's conclusions were not disproved, due to the existence of period of separation by density differences, thus making possible a substantial increase in the size range washed.

1912—Rheolaveur trough washer, developed by Antoine France, a Belgian mining engineer, and characterized by automatic recirculation of a middlings and fines product acting as a balance wheel to control the separation, installed near Liége about this time.





Left, a gravity-screen tipple of 1892; below, perspective drawing of a 1936 installation, Hardy Coal Co.

cular, motion, although one 1932 screen is stated to possess motion in three instead of two dimensions. Nearly all early screens were operated inclined. In the last five to ten years, however, particularly the last two, several vibrating and pulsating screens for operation either horizontally or with the discharge end higher than the feed end, have been offered.

As screening increased and prepared sizes grew in importance, elimination of breakage, particularly in the larger sizes, began to loom larger in the eyes of bituminous operators. With the harder-structure anthracite, chute loading still is the general rule, but at bituminous mines the chute, either stiff or hinged, has been largely replaced by the loading boom—at least for lump and egg—and in many recent plants for all sizes down to slack or screenings. Probably the first hinged loading boom was installed in 1908 at the Jeffrey-built Landgraff (W. Va.) plant of the Empire Coal & Coke Co. Few Illinois plants after 1910 failed to include booms for the larger sizes. Types now in use include the scraper (rescreening type patented by Link-Belt Co. in 1924), belt and steel apron, all with adjustable-height discharge ends. Along with the boom has come a steady increase in degradation screens for removing breakage from prepared sizes.

Box-car shipments go back to the early days of the industry and still are a major factor in certain regions, particularly the Rocky Mountains. This activity also has been revived in Illinois since 1930, and particularly in the past two years, after a virtual cessation about 1920. Special loading equipment was early devised, the Ottumwa Box Car Loader Co., for example, erecting a loader (unsuccessful) at the Ottumwa (Iowa) mine, Phillips Fuel Co., in 1895. This was soon followed by a second workable machine at the White Breast Fuel Co. mine, Forbush, Iowa. Ottumwa later took over the Christy loader, first built in 1898. Research and development by this and other organizations have resulted in a wide variety of types and capacities.

Miner Once Did Cleaning

Entire responsibility for coal cleaning doubtless rested on the miner in the early days and even now, with the more or less elaborate surface equipment, the hand miner generally is expected to remove as much of the refuse as possible. Exceptions include steep-pitch mining where coal is loaded from batteries, and also mines where mobile loaders or other self-loading equipment is employed and picking at the face would materially affect machine operating time. For many years, however, removal of the refuse underground was the only cleaning accorded both bituminous coal and anthracite.

Transfer of a part or all of the cleaning job to the surface directly reflected the increased use of the finer sizes. When only large coal was being loaded, the miner could easily pick out only the pure lumps. But when the size range was extended, some means of spreading out the coal, either in a sized or unsized state, so that impurities could be observed and removed, became necessary. Obviously, this could best be done on the surface, and the outgrowth of this reasoning was the picking table.

In the anthracite region, the first picking table was installed at the Hill & Harris colliery, Mahanoy City, about 1870. Its use immediately began to spread, but was challenged almost at once by the mechanical cleaner, now universal in anthracite, although picking to remove coarse refuse from large coal prior to crushing still is practiced at many collieries, particularly where the refuse content of the coal as loaded is high. In no case at the present time, however, is hand-picking alone relied upon in cleaning anthracite. Early anthracite picking tables were little more than stationary chutes. Later, the reciprocating, or shaking, table, now almost universal, was developed.

In the bituminous industry, where general adoption probably lagged behind anthracite use, the picking table still is the cleaning means for the majority of the tonnage shipped, although its supremacy is being challenged by the mechanical cleaner. Even where the latter equipment is used, hand-picking still remains the standard method of preparing the largest sizes, as the size of the pieces makes possible an efficient job at a reasonable cost. In the smaller sizes, even though tables have been widely installed for these grades in

late years, efficiency and uniformity are difficult to secure at a reasonable cost, and this, coupled with the practical impossibility of beneficiating minus 2-in. coal by hand picking, has been the compelling motive in many cases in a change to mechanical cleaning.

Probably the first bituminous shaking picking table was installed at the Champion No. 1 plant, Pittsburgh Coal Co., completed in 1928. The bituminous industry also developed the smooth-top apron-type table. Both types make it possible to pull, rather than lift, large pieces of bone and rock off the table, considerably increasing the output of the picker. At some anthracite properties the process is reversed and the coal is picked off. A retractile table with integral rescreen mounted on wheels to permit moving it back and forth to discharge to either the loading boom or mixing conveyor was a feature of the new 1935 Morrow tipple at the Wyoming (W. Va.) mine, Red Jacket, Jr., Coal Co.

Mechanical Cleaning Up

Advances in mechanical cleaning equipment have been the outstanding preparation developments in the last 25 years in both the anthracite and bituminous industries. In this advance, both industries, in addition to developments of their own and borrowed from overseas, have drawn on ore concentrators for thickeners, tables, filters, oil-flotation units, etc. Coal in the United States, however, is a relative newcomer to the mechanical-cleaning ranks, as hand jigs were used on coal in Saxony about 1830, probably suggested by earlier ore-dressing practice. Other significant overseas mechanical-cleaning developments, from early to modern times, are summarized in Table II.

Several types of washers used in this country are missing from the overseas list, although primitive prototypes of some were tried to a limited extent in earlier days on the Continent and in Great Britain. Dry cleaning, however, is purely an American development and this country also has led in the development and use of coal-washing tables, as well as processes using high-density mediums for cleaning, although the use of high-gravity liquids was suggested in England by Sir Henry Bessemer in 1858. Another Englishman, Rudolph Lessing, perfected the calcium-chloride "Clean Coal" process about 1926.

Anthracite probably led in the introduction of mechanical cleaning in the United States. Reflecting the more pressing problem in that particular region, due to the steeply pitching beds and the consequent necessity for loading a large amount of refuse material, early experiments took place in the Southern hard-coal field. Several crude jigs were tested near Pottsville between 1860 and 1865 and one or two small washeries were in operation prior to 1870. One of the earliest installations of record was a Stroh machine, Jeddo breaker, 1873. Incidentally, the inventor, who gave his name to the machine, was roughly handled by slate pickers, fearing the effect on employment prospects. First extensive washing probably was done by the Lehigh Navigation Coal Co. in the Panther Valley region about 1875.

Around 1890, mechanical pickers began to attract anthracite producers, particularly in the Northern field, although patents had been issued as early as 1875. Perhaps the best-known were the Emery picker and the Pardee spiralizer. The latter, patented in 1899, was later used in the bituminous fields. Other types included the Zeigler, Thomas, Devers, Mowry shaker, Ayres traveling belt, Norman (Frederick) roll picker, Mason & Allen picker, installed at a Hudson Coal Co. plant, 1911; Colvin picker, 1911; and the Mason picker, 1924. Pickers still are used for removing flats from cleaned anthracite, most companies relying on the slot or shutter type on a screen or in a shaking chute, although some use the roll type.

Jig Displaces Pickers

Mechanical pickers, however, gradually gave way to the anthracite jig, the various types including the Stroh, Christ, Snyder, Lehigh Valley, Wilmot-Simplex, Liberty, Reading, James (1919), Ransom and Reilly-Knapp, as well as a few bituminous types (Elmore, prior to the James, etc.). Concentrating tables began to make their appearance in the Southern fields about 1920, and in 1921 the first Chance sand-flotation equipment was installed at the West Nanticoke colliery of Staples & Bell. With the rise of these and other later cleaning units, the jig began to decline in importance although still a major type of equipment.

Rise of the newer anthracite types of equipment may be credited to increasing demand for better cleaning, emphasis on decreased operating cost and growing use of smaller sizes. Jigs were and still are an efficient cleaning medium, but in general the anthracite types are limited in capacity and with the demand for cleaner coal this capacity had to be reduced still further in many cases to meet requirements. Consequently, large numbers of units are necessary, with attendant labor and maintenance cost. Capacities have been substantially increased on certain late-type jigs, however, such as the Wilmot-Simplex units with capacities of 75 tons per hour on certain sizes used by the Philadelphia & Reading Coal & Iron Co. Uniformity of results also was difficult with the earlier jigs, particularly in washing the smaller sizes, and this the newer cleaners promised to correct.

New Processes Start

The first of the concentrating tables previously used in bituminous cleaning were introduced in the anthracite region in 1916. The original table, of the ore-dressing type, was soon replaced by tables designed for coal washing, and in 1920, the first Deister-Overstrom "Diagonal-Deck" tables were installed at the Wadesville plant, Philadelphia & Reading Coal & Iron Co. A second installation was made about the same time at the Loree colliery, Hudson Coal Co. Widespread adoption of these tables followed in succeeding years and their installation, usually for sizes from buckwheat down, still is active. Other types are the Plat-O, Campbell, James, etc.

The Chance process, in which the separating medium consists of a high-density mixture of sand and water, has moved into the lead among modern methods for cleaning anthracite since the first Staples & Bell installation. Early Chance cones were designed to handle the entire size range of feed, but since the development of the square-topped cone in 1928, the general practice is to employ it for cleaning steam sizes. A substantially similar process was the Conklin, with which the Hudson Coal Co. experimented in 1921. Magnetite was employed to secure the high density required, and the Dorr thickener was used in its recovery and recirculation.

In 1924, the Rheolaveur process was introduced into the anthracite field from Europe. The earliest installation, at the Baltimore colliery, Hudson Coal Co., included both coarse- and fine-coal washers, and was followed by immediate erection of a number of major plants, with additional installations in later years. A redesigned coarse-coal unit was offered in 1931 and included in succeeding installations, as well as in rebuilding some earlier installations. As in other major processes in use today, separate

units are provided for coarse and fine coal.

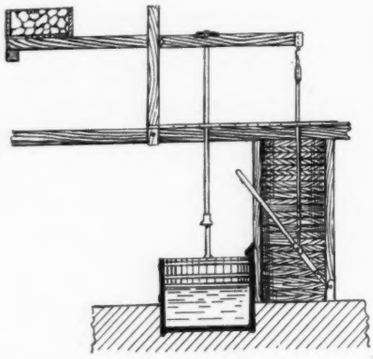
The Menzies hydroseparator, an upward-current unit-type machine in which water is circulated continuously by a centrifugal pump, was another 1924 offering widely adopted in later years. In many cases, entire breakers were equipped with this machine, the jigs being moved out and the hydroseparators in. Later improvements in the hydroseparator include float control, tandem and three-compartment units, and special models for flats.

The Hydrotator, essentially an upward-current washer incorporating the hindered-settling principle, supplied with a continuous current of water by a centrifugal pump and revolving agitator arms, was introduced in 1925 after preliminary experiments at the Oak Hill colliery. In 1932, the machine was equipped with a separate recleaning unit arranged to provide automatic reject control and replacing the recleaning cone and small concentrating tables used on previous models. Later, in 1935, tank shape was modified to make possible the discharge of larger and heavier refuse, thus increasing capacity and size range (*Coal Age*, August, 1936, p. 351). The recleaning unit was discarded and a float control installed.

Cleaner Perfected in 1934

The latest major equipment developed in the anthracite field is the Menzies cone separator, in which stratification is accomplished by an upward current of water supplied by a centrifugal pump, assisted by an agitator (*Coal Age*, February, 1935, p. 59). The water-column principle of automatic regulation is employed. Eight units were installed in 1934, and construction since that time has included a number of complete plants, such as that of the Sullivan Trail Coal Co. (*Coal Age*, March, 1936, p. 97). Prepared sizes are cleaned in one separator and steam sizes in another at Sullivan Trail. Use of cone-type separators employing water as a separating medium goes back, however, to 1916, when the Lehigh Navigation Coal Co., after unsuccessful experiments on sizes up to about egg, began installation of a number of units adapted from the Robinson washer to clean silt.

Mechanical cleaning in the bituminous industry began almost with the advent of this activity in the anthracite region and developments have roughly paralleled those in the hard-coal field, with perhaps one important difference — mechanical pickers were adopted by only a few soft-coal mines, whereas pneumatic cleaners have never broken into the anthracite industry. The first bituminous washery, using a piston jig, was constructed at Alpsville, near Pittsburgh, Pa., in 1869, to clean slack from neighboring mines for coking. The second bituminous washery, employing an Osterspey piston jig with differential motion and flap valves on the piston, was completed at East St. Louis, Ill., in 1871, by the Illinois Patent Coke Co.



The hand-operated movable sieve used in Saxony in 1830.

In western Kentucky, a sluice washer was installed by the St. Bernard Coal Co. in 1882. Later, it is reported, the coal was recleaned in a jig. To the same mine Prof. A. C. Campbell brought a model of his bumping table in 1891. In 1890, the first Luhrig jig washery in the United States was erected at the City Furnace plant, later a Sloss-Sheffield Steel & Iron Co. operation, in Alabama, an early leader and still a strong advocate of washing. The second Luhrig jig washery went to the Brush Shaft, Illinois, in 1894. A tub washer somewhat similar to the Robinson washer was developed in Illinois by Howe in 1888 and the first installation was made by the Wilmington Washed Coal Co. in 1891.

In 1892, the first Robinson washer was installed at Slope No. 1, Tennessee Coal, Iron & R.R. Co., Pratt City, by Erskine Ramsay. Shortly afterward, a similar unit was installed at Slope No. 2. In this installation, however, the pump sump used on the English machines was replaced with the Ramsay sludge tank, credited with making the machine a really efficient coal washer. Many machines (112 were listed by Jeffrey in 1900) were later installed in Alabama and elsewhere.

Alabama also was the scene of much of the preliminary work of Stewart, who early echoed Baum's slogan of washing before sizing and developed the Stewart pan jig, first installed by the Big Muddy Coal & Iron Co., Illinois, in 1898, and next at the Brookwood mine, Alabama. A Scaife trough washer, probably the first, was installed at the Braidwood (Ill.) mine of the Maltby Coal Co. in 1898.

The Elmore plunger jig, with plunger equipped with flap valves to reduce suction, was developed about 1900. The Montgomery jig came out in 1910. Advent of many other bituminous jigs used may be judged by Illinois installation dates, as follows: Forrester, 1894; American, 1904; New Century, 1906; Shannon, 1907; Foust and Pittsburgh, 1909. In addition, several anthracite jigs were tried and the Wilmot-Simplex has several bituminous installations to its credit in late years. Significant in United States jig development was the preoccupation of many designers with elimination of violent suction stroke, still a major objective in jig design.

After the Campbell table, the next major step in concentrating-table development took place in the Rocky Mountain region. The Stag Canon Fuel Co., Dawson, N. M., experimented with a Wilfley table, originally for ore dressing, in 1906, and in 1911 installed a larger Wilfley unit, which later led to the purchase of 24 units of the Massco type (the Wilfley table for coal washing). The Deister-Overstrom "Diagonal-Deck," Butchart, Plat-O and Overstrom tables were first used in coal preparation in this plant in 1916 or 1917.

New Cleaners Adopted

As in anthracite, the years after 1920 were marked by a rapid rise in new types of cleaning equipment. In that year, the percentage of bituminous production mechanically cleaned reached the bottom of the decline which started in 1915 largely as a result of war conditions after a steady rise from 1906, the first year for which data were collected. Since 1920, the percentage output, Fig. 2, has shown a steady rise, which promises to continue. Illinois, which practically abandoned mechanical cleaning after leading the country in 1908, is contributing a substantial share to the total in late years, led by stripping concerns. And in late years, more mechanically cleaned coal is going into general markets, as compared with the coking objective of earlier times.

Air cleaning—the subject of patents as far back as 1850—started its

upward march in 1919. Dry mechanical separators, however, had previously been employed at bituminous plants in Illinois and the Rocky Mountains, the most notable installations being the spiral separator plants of the Old Ben Coal Corporation around 1912 to 1915. In 1931, Cumberland mechanical pickers, developed by W. W. Stevenson, were installed by the Steinman and Splashdam coal companies, in Virginia, and in 1933 an experimental Allen & Garcia "Mekanopic" picker was installed at the No. 18 mine, Peabody Coal Co., West Frankfort, Ill.

The first modern air-cleaning unit was the American pneumatic separator, or table, developed from the Sutton, Steele & Steele separator used in cleaning seeds. This separator combined a shaking movement with an upward current of air through a riffled deck. The first installation was made at the McAlester-Edwards Coal Co. mine, McAlester, Okla., in 1918. The first commercial plant was that of the St. Louis, Rocky Mountain & Pacific Co., Raton, N. M., 1919, and the second that of the American Coal Co. of Allegany County, McComas, W. Va., 1923. Early units were applied largely to the finer sizes, but in 1925 McComas installed five Y separators, with the advent of which the upper size limit was raised to about 3 in. About 1930, with the development of the R separator, installations were offered for cleaning an unsized 3x0-in. feed, either on a single table under easy cleaning conditions, or on a series of tables re-treating progressively smaller fractions of the feed to the preceding units, under difficult cleaning conditions.

The first of a number of Peale-Davis "Pneumo-Gravity" separator installations was made at a mine of the Peale interests, central Pennsylvania, in 1923. A feature of this process was dry-cleaning an unsized feed up to 4 in., using a secondary table to reclean a refuse product from the primary table. In certain later plants, three tables were employed, a secondary table taking the refuse and fines from the primary table, with a final re-treatment unit to handle the refuse from the second table.

Certain wet-washing processes which started in the anthracite field began to move into bituminous regions in 1925, with the installation of a Rheolaveur plant at the Cokedale (Colo.) plant of the American Smelting & Refining Co. and the erection of a Chance plant at the Mt. Union (Pa.) operation of the Rock Hill Coal & Iron Co.

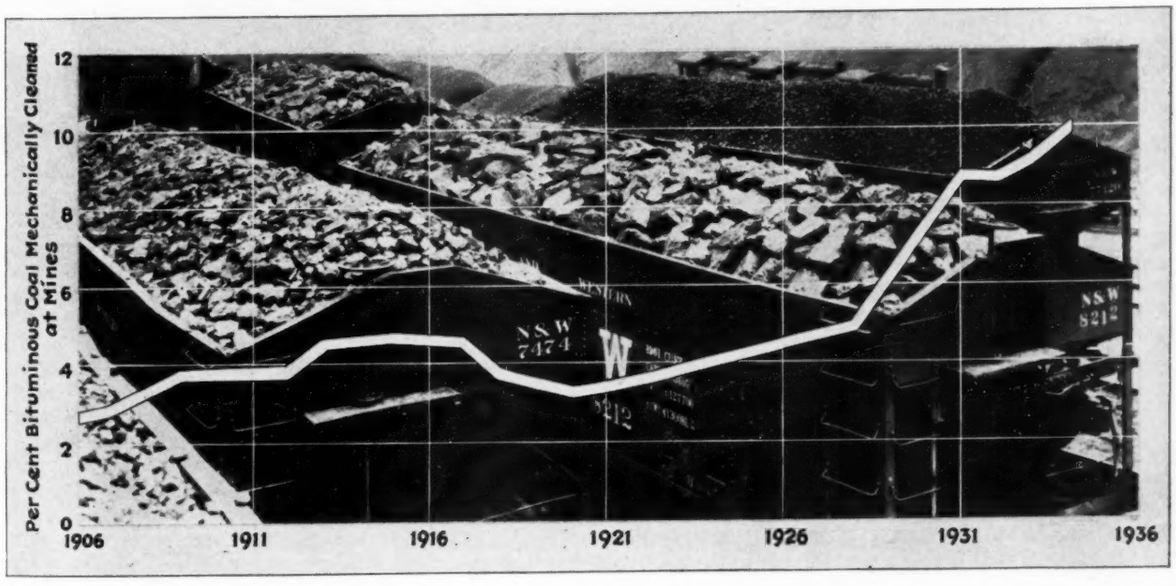
Beginning in 1928, a number of Rheolaveur plants were installed in Pennsylvania and West Virginia, and in 1931 a small slurry washer was installed in Illinois—the forerunner of two additional plants with capacities of 600 or more tons per hour in 1935 and 1936. Early Chance installations at soft-coal mines were confined largely to Pennsylvania. Later, plants were erected in Ohio and West Virginia and in 1935 the Bell & Zoller Coal & Mining Co. built a combination plant with a capacity of 1,000 tons per hour at Zeigler, Ill., using Chance cones for washing 6x$\frac{5}{16}$-in. coal and Stump "Air-Flow" cleaners for preparing the fines.

The Menzies hydroseparator was introduced into the bituminous fields in 1926, where it was employed largely on egg, stove, nut and similar sizes. In addition to widespread installation in other fields, this equipment was extensively adopted in the Pocahontas region in 1928 for cleaning intermediate sizes.

Up to 1925, it will be noted that few mechanical cleaners attempted to handle material over 3 in. in size and the maximum was 4 in. in a few plants. In fact, one engineer expressed the opinion in 1926 that mechanical cleaning of sizes over 2 in. was uneconomical as a general rule. Later developments in equipment and practice and the high cost of picking labor have, however, resulted in a number of cases in the use of mechanical cleaners on sizes up to 6, 7 and 8 in.

The year 1928 marked the first installation of the Baum-type jig in the United States, although the first on the continent was installed in Nova Scotia in 1912. Introduced from England and christened the Link-Belt-Simon-Carves jig, the 1928 unit went in at the Pittsburgh (Pa.) plant of the Jones & Laughlin Steel Co. to wash minus $\frac{3}{4}$-in. crushed coal for coking. The second unit, first at a mine, was erected at the Allendale No. 2 operation of the Central Indiana Coal Co. in the same year. A second Baum-type jig was imported from England and installed by the Montevallo Coal Mining Co., Aldrich, Ala., in 1931, to wash 4$\frac{1}{2}$x0-in. coal. This type is now manufactured in the United

Fig. 2—Percentage of bituminous coal mechanically cleaned since 1906.



States under the name McNally-Norton.

Another dry cleaner, developed by Fraser and Yancey and known as the air-sand process, was installed at the Cadogan (Pa.) plant of the Allegheny River Mining Co. in 1930. This unit, for nut coal, was of the two-compartment type, with the primary compartment for the major cleaning operation and the secondary compartment for re-treating refuse to complete coal recovery.

Cleaning by the air-sand process is essentially a float-and-sink separation of coal and refuse in a bed of sand made fluid by bubbling air through it. Specific gravity is varied by varying the flow of air. In the Lundale (W. Va.) plant of the Logan County Coal Corporation, completed in 1935 and cleaning 3x¼-in. coal in two separators, three-compartment units are employed. One compartment receives the raw feed and discharges the coal end to the second, where it is re-treated. Refuse from these two compartments is re-treated in a third. The coal end from this third compartment is discharged into the first for supplementary treatment with the raw feed.

Cleaner Offerings Wax

In 1932, an experimental Wuensch "Differential-Density" washer was installed at the West Mineral plant of the Pittsburg & Midway Coal Mining Co. The process depends upon the formation of a high-density liquid through mixture of the impurities in the coal with the water in a classifying cone. Later, a full-sized commercial unit went into regular service at the mine.

The Stump "Air-Flow" cleaner was another 1932 development. In this cleaner, an intermittent air current supplied by a force fan and pulsator, or revolving shutter, is forced up through a resistance element installed between two previous plates forming the coal cleaning deck. Provision for taking off a middlings product is a feature of the unit. The first major installation was made in 1932 by the Barnes Coal Co., Barnesboro, Pa., for cleaning 3x0-in. coal.

In 1934, the Jeffrey Baum-type jig with air valves placing control of both pulsion and suction strokes in the hands of the operator was introduced, along with the Jeffrey diaphragm jig, in which the strokes are produced mechanically by cams and arms operating molded-rubber diaphragms. Both types feature straight-line flow, automatic refuse withdrawal and adjustable features to give flexibility in service. The diaphragm principle also was a characteristic of earlier ore-concentrating jigs, including the Cooley and Bendelari of 1928 and earlier.

The Llewellyn jig, in either the single or tandem models, was brought out in 1935, featuring, in the two-stage unit, sludge recovery, primary cleaning and rewashing in the same unit with recirculation of middlings or their separate withdrawal. Plungers in this jig are fitted with flap valves to eliminate back suction and also are hinged at one end to give a varying vertical action of the water from the feed to the discharge end of the washing compartment.

Introduction of a successful calcium-chloride washer — the Fuel Process unit—several of which were installed in the low-volatile fields of West Virginia, was another 1935 development. This washer employs a solution with a specific gravity slightly higher than water to which a slight velocity is imparted by impellers. The Vissac jig also was introduced from Canada in 1935, with installations by the Snow Hill Coal Corporation, Terre Haute, Ind., and the Northwestern Improvement Co., Roslyn, Wash. In this jig, embodying a modification of the principle of the Richards and Denver Equipment Co.'s pulsator jigs, primarily for ore-concentration, water under a constant head compresses air in a closed chamber. Admission of water to the washing compartment is controlled by a butterfly valve which, upon opening, allows the water to be forced into the wash box by the pressure of the compressed air assisting the pressure head developed by the water column itself.

Uniformity Stressed

Preparation developments in recent years also have been marked by increasing attention to uniformity of product from both the chemical and size standpoints as a means of assuring best results in utilization by the consumer. At first studied primarily in connection with chemical characteristics, uniformity is now gaining ground from the standpoint of the size consist of the various grades. This has been reflected in late years, for example, in the use of storage bins for the two or more smallest sizes at several Illinois operations to permit control of the size consist of the various resultant coals. Some of the newer plants in other fields also, notably those of the Island Creek Coal Co., in West Virginia, include storage bins for this same purpose.

Natural drainage on screens or in bins or cars is the general practice in the anthracite region, one exception being the use of classifiers or thickeners of various types on very fine coal in certain cases. This long-established custom is accepted by the market with little question, but in the bituminous region wet coal, both from the standpoint of the moisture content itself, as, for example, in coking coal, and from the freezing-in-transit angle, has called forth much study. Above ¼ or ½ in., natural drainage usually gives an acceptable product and it is with sizes below these limits that preparation men have been most concerned in late years. One of the major arguments for dry-cleaning equipment has been elimination of water, particularly in cleaning fines, and this contention has been reflected in combination plants using water for the larger sizes and air cleaners for the small coal. Many operators in late years, however, have chosen water for the entire mechanical cleaning job, supplementing washing equipment with mechanical dryers or filters, heat dryers or, in some cases, special dewatering screens. In other cases, particularly in the last two years, chemicals are applied to the coal to keep it from freezing in severe weather.

Drying Some Years Old

Both mechanical and heat dryers go back some years in the United States and were preceded by various types of draining equipment, including pits, such as those installed by the Cambria Steel Co., Johnstown, Pa., about 1904; elevators, conveyors and similar machines. Under the pit system, the coal was allowed to stand long enough for the moisture content to reach the desired figure. Early mechanical dryers of the centrifugal type include the Wendell (developed in Illinois about 1914) and the American or Elmore (developed at Steelton, Pa., also about 1914). The following year two American and three Wendell units were in operation in Alabama. Ruggles-Cole revolving kiln-type heat dryers were in use at the Cottonwood (Mont.) mine of the Cottonwood Coal Co. in 1919. The Carpenter centrifugal dryer was developed by H. B. Carpenter, superintendent, byproduct plant, Colorado Fuel & Iron Co., about 1920, after earlier experience with the Wendell, and the first installations were made about 1924. The Laughlin filter was introduced about 1926.

The latest cycle of dryer installation dates back to 1928, when the

Pittsburgh Coal Co. installed three Carpenter dryers in Champion No. 1 central cleaning plant that year, followed by four each at Champion Nos. 4 and 5 in 1929. Seven Christie heat dryers went into service in 1930. Carpenter dryers also were included in the Clairton plant of the Carnegie Steel Corporation, started up in 1931 ($\frac{3}{8}$x0-in. coal from dewatering screens) and the Nemacolin (Pa.) plant, Buckeye Coal Co., started up in 1930. The Nemacolin installation also included a Christie direct-heat dryer for use when producing steam coal.

The D-L-O dryer, a modification of the Dwight-Lloyd sintering machine, in which the coal to be dried is carried on perforated plates suspended between conveyor chains, was developed at the Friar Tuck (Indiana) mine of the Sherwood-Templeton Coal Co. in 1931. A stoker-fired furnace supplies heated air, which is drawn through the coal by an exhaust fan. In 1933, K. R. Bixby installed at the Farmington (Ill.) mine, Midland Electric Coal Corporation, a dryer consisting of upright cylinders with suitable interior means to permit the coal to cascade down from top to bottom along with a current of heated air supplied by a stoker-fired furnace. Three other Illinois plants since that date, including one now under construction, have been equipped with either or both mechanical or heat dryers. Equipment in the new Willow Grove No. 10 cleaning plant of the Hanna Coal Co., Ohio, completed this year, includes a Link-Belt "rotary louvre heat dryer," also reported to be slated for installation in a number of other recent washeries.

Filters Enter Picture

Filters are another type of equipment coming more into use, particularly in the Pittsburgh (Pa.) district, because of restrictions on wasting black water into streams. The Pittsburgh Coal Co. installed Laughlin filters in 1928 and Dorr and Oliver filters in 1930, followed by a Genter filter at Clairton and an American filter at Nemacolin. At Nemacolin, experiments with pelletizing filter cake in a drum prior to drying it in a D-L-O machine were carried out in 1933. All large filters now used in coal preparation are in the Pittsburgh district, with twelve rotary vacuum units with a combined filtering area of 5,680 sq.ft.

The extension of wet washing also has brought about a general improvement in water-settling equipment. Correction of the inefficiencies and control difficulties of early types of drag sludge tanks are the aims in the newer types of units, including the Dorr thickener, first installed at the New Mexico plant of the Stag Canon Fuel Co., in 1916. A total of 80 Dorr-type thickeners with a combined settling area of approximately 222,000 sq.ft. have been sold to anthracite and bituminous producers.

Flotation Use Starts

With recovery of fine coal coming more to the front at a number of operations, preparation men have turned to a consideration of flotation as a means of cleaning extremely fine sizes. Although flotation goes back a number of years (first experiments on coal were made at the Mellon Institute in 1918), installations as yet have been few. Experiments with the Arzinger oil-flotation system were reported in Alabama in 1928. This was followed by an installation at the Natalie (Pa.) operation of the Colonial Coal Co. In 1931, McIntosh and Denver cells with a capacity of 20 tons per hour were installed at the Champion No. 5 plant of the Pittsburgh Coal Co. The West Mineral (Kan.) plant of the Pittsburg & Midway Coal Mining Co. was equipped with Denver cells in 1934 for cleaning 2-mm. material from a Dorr thickener.

Growth in the use of domestic stokers has brought about still another refinement in bituminous preparation in the last five years: viz., dedusting. Although suggested as a means of alleviating the sludge problem in wet-cleaning plants, actual practice so far has been almost entirely directed toward the removal of dust from stoker coal. Equipment most generally used is high-speed short-stroke shakers or vibrating screens. At the Enos Coal Mining Co. operation in Indiana, water sprays are combined with Tyler electric vibrators to eliminate variations resulting from variation in moisture content of the strip coal produced (*Coal Age*, September, 1936, p. 371).

Aspirating units of various types make up the second class of equipment with the Chicago, Wilmington & Franklin Coal Co., Illinois, as one of the first to employ units of this type in a pilot plant erected in 1931, followed by a full-scale plant using a Birtley-type aspirator with improvements by Thomas Garwood in combination with electric vibrating screens. Algar dedusters were included in an installation of the Peabody Coal Co., Harco, Ill., in 1934. Birtley dedusting units and auxiliaries figured in an installation of the Pittsburgh Coal Co., Imperial, Pa., in 1935, following closely C. W. & F. practice. Magnets for removal of tramp iron are another preparation development which has received added impetus from the growth of stoker sizes.

Treatment of coal to prevent flydust in the home or at other points of use is another recent bituminous preparation development which has made major progress in the past five years. Initial development is credited to three operators in the low-volatile fields of southern West Virginia who began experiments with calcium chloride in 1926. Since that time a wide range of materials has been applied to coal to render it dustless in addition to calcium chloride, including various chemical solutions, miscible oils, paraffin (Old Ben Coal Corporation, Illinois, 1931) and hot and cold oil. Starting with an early installation by the Franklin County Coal Corporation, Inc., at its Royalton No. 7 mine, Royalton, Ill., in 1934, the "hot-vapor" oil process has staged a rapid advance in many of the producing regions of the country. And lately equipment has been offered for atomizing cold oil at high pressure prior to application to the coal.

Trough washers used prior to 1556
Water trompe

STYLE AND EFFICIENCY STAGE REVOLUTION IN THE FAMILY CELLAR

By ALLEN J. JOHNSON
Director, Anthracite Institute Laboratory
Primos, Pa.

CORRECT humidity and comfortable temperatures are such close companions to health and happiness that it seems natural to suppose that everyone would have at least a working knowledge of all types of heating equipment. Unfortunately, this is by no means the case. As a matter of fact, the cellar and its comfort-making machinery are in many cases the most neglected and least understood parts of the entire house. Persons who can explain the theory of radio and talk freely of free wheeling are frequently surprised when told of the tremendous strides which have been made in heating and air-conditioning during the last quarter of a century.

Twenty-five years ago the cellar was a damp, dirty place where an industrious spider could work all day in perfect security; today the same cellars are useful, attractive floors. Game rooms, laundries, gymnasiums and workshops have moved into them and found them to be very worth-while places indeed. Dampness and dirt disappear with a little heat and habitation, giving the cellar many advantages, not the least of which are the confining of a large part of any noise to the premises and the saving of wear and tear on furniture and valued possessions.

This new interest in the cellar is paralleled by an entirely new style in the design of heating equipment. The old furnace, built for utility alone and covered with patches of asbestos, has been supplanted by attractively jacketed heaters resplendent in colored enamel and chromium trim. As adequate insulation has been included, these have done more than merely brighten the corner of the play room.

With attention of this type focused upon the cellar it was inevitable that other and vastly more important improvements in the heating equipment itself would follow. These developments fall into two very distinct classes: improvements in the heating systems proper and perfection of auxiliaries.

Twenty-five years ago, "hot-air" systems were largely a hit-or-miss arrangement, at the mercy of gravity and local circulation problems. Today the simplest plants are installed with the tremendous advantage of a full knowledge of the laws of convection and gravity flow. At but slight additional expense circulating fans are available to force warmed air into the farthest and coolest corners of the house.

ALLEN J. JOHNSON

Who this month celebrates the tenth anniversary of his association with the anthracite industry, upon being graduated from the University of Delaware in 1921 entered the employ of the Atlantic City Gas Co. Next he became assistant power engineer for the Atlantic Refining Co. and was in charge of efficiency and experimental testing and developments upon boilers and other power-plant equipment. At the time the erection of the laboratory of the Anthracite Institute was authorized, Mr. Johnson, then a combustion engineer on the staff of Anthracite Coal Service, was given the job of designing the new plant and was made its director.

Winter air-conditioning — an entirely new industry—is an evolution of the old "hot-air" furnace. At surprisingly low cost air is cleaned, heated, humidified and forced into the living rooms under full thermostatic control. Such systems are in such increasing favor that it is safe to predict that these will be the predominating heating systems for the homes of "tomorrow" irrespective of their size or cost.

Vast improvements also have been made in piped systems of heating. Small motor-driven pumps provide forced circulation to hot-water systems, thus eliminating the one outstanding objection to this type of heating: i.e., a tendency toward sluggishness upon acceleration. Improvements in valves in steam systems insure much more positive distribution of heat to all radiators and eliminate the necessity for troublesome "vent" valves. The past quarter of a century also has witnessed the introduction of almost countless other improvements, including the development of entirely new systems. Outstanding among these are the closed hot-water system of piping which permits the carrying of higher water temperatures. Vapor-vacuum systems, with characteristics of very rapid, dependable heating, mostly for larger homes and buildings, also rose to popularity during this period.

Slightly over 25 years ago the thermostat was offered as a means of automatically controlling the draft dampers of a coal-fired furnace. In intervening years quality and dependability have been improved to a point where almost exact temperatures may be maintained throughout the entire winter with an absolute minimum of attention to the heater. In addition, the price of these devices has been reduced to such a point that the savings in fuel alone usually will defray their initial cost.

The magazine-fed boiler is the next logical step toward automatic heating. Similar to conventional boilers in outward appearance, magazine heaters have an internal storage space for sufficient coal to last for at least 24 hours. When used in conjunction with thermostatic controls, such heaters completely eliminate the necessity for any attention from the women of the family. As an added feature they frequently are designed to burn smaller and less expensive coal, thus operating at a very low fuel cost.

Even in the face of widespread

research and remarkable developments, it is safe to predict that the domestic coal burner, a development of the last ten years, will stand as a modern method of heating for many years to come. Coal, is, without question, the safest of all fuels. Other advantages include low cost, a practically unlimited supply, and even burning, a characteristic which particularly commends it as a domestic fuel. The development of the coal burner adding the convenience of complete automatic heat, with a retention of all of these advantages, is thus an extremely worth-while contribution to the heating advancements of this quarter century.

Coal burners, in spite of their youth, have been developed to an extremely high state of perfection. Because of their rugged construction their life span is so great that they can be safely amortized over a longer period than any other similar equipment. Types are available to meet every condition of demand and purse. First is the burner that feeds and burns coal under thermostatic control, with ash removal in the conventional manner. A more advanced, and perhaps the most popular, type removes ashes to covered cans where they are readily accessible to the ash man. The most recently developed burner removes coal directly from the main storage bin, thus providing a completely automatic installation. The popularity of this latter type, together with its absolute labor-free yet economical operation, has already attracted the attention of practically every manufacturer in the industry.

In several advanced burner installations twelve-month operation for supplying both heat and service water is secured automatically. Coal conveyed directly from the storage bin is burned, and the resultant ash is even conveyed outside of the house, where it is picked up by the ash trucks. Such units have operated for months at a time without service attention of any kind, yet their installed cost is actually less than for oil or gas equipment of similar capacity.

No article on coal-burning equipment would be complete without a discussion of progress in connection with supplying service water (hot water for kitchen, bathrooms, etc.). An outstanding development is the indirect heater, which by means of a simple copper coil transfers the heat in the main boiler to the water in the storage tank. Year-round use of this system is rapidly increasing in popularity. In such cases, a very low fire is maintained in the boiler during the summer. While the fire is too small to heat the house, it is, nevertheless, available at all times in the event that the thermostat calls for heat.

Magazine-fed tank heaters are available to give a constant water supply with 24- to 48-hour-attention intervals. Even the lowly bucket-a-day stove is coming into its own with the perfection of effective temperature regulators which have the added advantage of stabilizing and prolonging the fire. As heating service water with gas or electricity costs many times that of coal, coal-fired service-water heaters of all

NON-FUEL USES FOR ANTHRACITE

- At least one important non-fuel use for anthracite has been discovered during the last few years: i.e., as a replacement material for sand in water filtration beds. Universal success in connection with experimental beds located in every section of the country indicates that a widespread adoption of coal as a filter medium is inevitable.

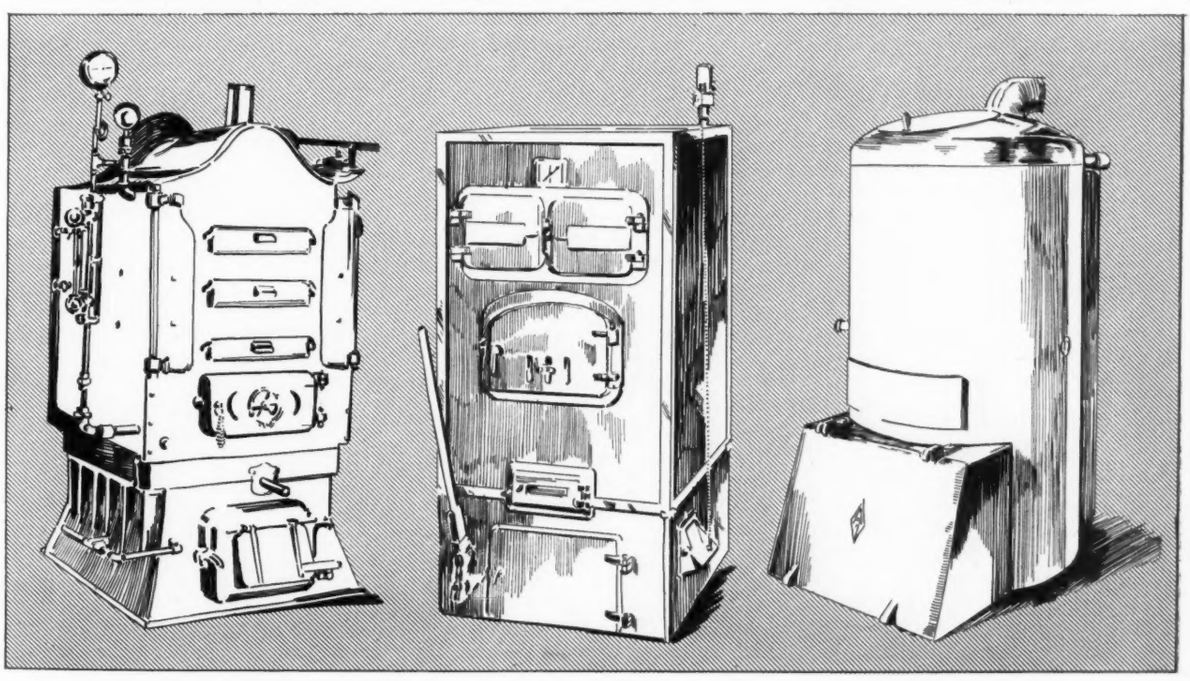
- As anthracite is used also to a limited extent in certain metallurgical processes, it is entirely possible that research will expand this usage. Research studies have indicated even further possibilities including the use of anthracite as an activated carbon, as a source for free hydrogen, as a material in the production of iron, for decolorization processes, and in industrial processing.

- Development of uses for ashes and breaker refuse, and the extraction of sulphur from mine water also are worthy of consideration.

★ ★

Past, present and future in home-heating equipment

A modern boiler of 1902 **The jacketed boiler of today** **Designed for tomorrow's cellar**



types are proving to be extremely popular.

There have been some very pessimistic predictions with regard to the part which coal will play in the future of heating. There can be very little doubt that competition from all fuels is here to stay. Therefore, if we are to regard the future prosperity of the coal industry as dependent upon the return of the near monopoly which it once enjoyed, such pessimism probably is justified. From any other angle, however, the outlook for coal actually is more promising than for any other fuel. The impending shortage of crude oil most certainly is a greater source of concern to oil interests than is competition to us. Manufactured gas is in a somewhat healthier position but costs are high and are dependent upon coal, whereas many thousands of dollars must be spent on enlarged mains to care for any rapid increase in house-heating loads.

Then, too, a large part of the popularity of oil and gas burners is due to their newness, which gave the public only one side of the story. Developments in connection with the automatic use of coal are advancing rapidly, whereas both oil and gas seem to have reached their peak of perfection, a fact which undoubtedly will aid coal in proportion to the speed with which the public can be fully informed concerning the possibilities and advantages of the new fashions in coal burning.

Institute Laboratory

The Anthracite Institute Laboratory has been active in the development of several novel and interesting devices for burning anthracite. Included among these are a service-water heater which requires attention only about twice a week, a combined boiler-burner which is completely automatic even to the removal of ashes outside of the cellar, and a conveyor for removal of ash to any desired point. Unfortunately, the placing of this equipment upon the market is as great a task as its development. Therefore, while active measures are being taken in all cases and while the merchandising of the equipment is imminent, it is not yet actually available.

Development of equipment, however, is only one phase of the activities of this laboratory. Another important function is the collection and dissemination of all types of information regarding the combustion of anthracite and the use of anthracite-burning equipment and auxiliary devices. Intensive studies have been made of the relation between anthracite and various competitive fuels. In one such study oil, gas and anthracite were successively used to heat an actual home. Results covering comfort, evenness of heat, reliability of equipment, and many other interesting phases, were studied, and are being presented to the retailer in an attractive eight-page bulletin.

The practice of the laboratory in carefully studying anthracite equipment and of approving those devices which are found to be satisfactory is becoming a well-known function. While it is not claimed that the laboratory's opinion is infallible, its approval, nevertheless, guarantees that the equipment has been rigidly inspected, both in the laboratory and in the field, and obviously does not possess any glaring defects. Failure to approve equipment likewise implies that the manufacturer has either not cared to trust it to the laboratory's decision or that, having been submitted, definite defects have been discovered which, in the opinion of the laboratory, would impair satisfactory performance.

VENTILATION

IN THE EARLIEST years of coal mining, drifts and shallow shafts could be used as approaches to coal seams, hence little methane was encountered. Coal also was mined without explosives, and mines were lighted by candles that did little to befoul the mine air. Workings were limited in area and, accordingly, blackdamp was relatively rare. For all these reasons, mine ventilation did not become a vital necessity for centuries, though working in unventilated mines must have been a distressing experience.

However, the time for mining deeper and more gassy seams eventually arrived, and severe explosions occurred. Perhaps the earliest explosion of importance in Great Britain was that at Mostyn Colliery, South Wales, described by Roger Mostyn in 1677. When, toward the close of the seventeenth century, firedamp was encountered in dangerous quantities, an effort was made to clear it away by burning it with candle flames while men were still in the mines and to remove accumulations of it that had collected during the night by sending men into the workings, sometimes criminals or penitents, clad in water-saturated clothes, carrying lighted candles mounted on poles to ignite the accumulation. Sometimes the candle was run in on an endless wire and in other places an inflamed rope that had been dipped in tar was thrown into the air to ignite the gas. In Lord Dudley's Netherton mines, methane was regularly fired at 4 a. m., noon and 7 p. m.

At most mines, some degree of ventilation naturally established itself, and it was made more effectual by "face airing," the placing of stoppings so that what air was available would go to the face. Not, however, until Captain Spedding, in 1760, deliberately planned the course of the air all through the mine by a method he termed "coursing," was anything resembling a true system of ventilation developed, but eventually air thus circulated sometimes traveled 30 or 40 miles before leaving the exit.

In 1810, John Buddle laid out his mine in panels with large pillars between adjacent panels, so that squeezes would not overrun the mine but also so that he could split the current and give each panel its modicum of air, thus preventing an explosion from involving the entire mine. To compel air to travel the workings, "trompes" were devised in which water fell at first freely and later in a long vertical box with slats slanting in opposite directions, so that the falling water carried air along. Sometimes a brazier of burning coal and subsequently steam jets or steam-driven pumps at the foot of the shaft were used to lighten return air, or sprays were provided to cool the intake and increase its weight. Induced ventilation by water or brazier was used in 1606, as Dr. Plot refers to it in his book "Staffordshire."

Furnace ventilation must have been early, for the "Compleat Collier" in 1708 declared that in the fiery mines of the North of England, furnaces were too risky to use. Early also, these were designed to be fed with intake air, the air of the mine being carried by a "dumb drift" into the air shaft many feet above the fire, so that the methane

in the mine would not be ignited. The furnace in some cases was placed at the surface with an inclined drift to the air compartment of the shaft and a high stack. Provision, of course, was made to keep the mine air from contact with the flame and with the sparks from the furnace.

Still later, an attempt was made to create ventilation by a reciprocating engine which drew in air at several points and expelled it at others. Of these engines, none of which furnished a continuous supply of air, but rather a series of puffs, the principal were Nixon's, the Struvé and the Hart blowers. Usually two engines working alternately were provided, so that the current was not wholly discontinuous.

Though the fans first introduced had vertical axles, they soon were set horizontally. Devised by a Liége (Belgium) engineer, the Guibal fan made rapid progress throughout Europe and in the anthracite region of Pennsylvania. It had straight blades set on bars projecting from an octagonal frame around the shaft. These blades, which did not run to the fan center, delivered their air to a housing that, at first, was not a scroll; however, a curved baffle, which could be adjusted, compelled the air to travel through the housing to an *évasé* stack. Where blades, housing and *évasé* were of wood, the fan could be made by a mine carpenter.

Apparently, the first mine fan in the United States was supplied, 1857-1858, by J. L. Beadle for a mine at Locustdale, near Ashland, Pa., in the Western Middle anthracite field. G. W. Snyder, of Pottsville, Pa., erected a fan at St. Clair, in the Southern anthracite field, in 1866. In a few months thereafter, a blower fan was installed by Beadle and Snyder at Williamstown, Pa., also in the Southern field. The first mine fan in the Wyoming Valley was perhaps that erected by George Parrish in 1867 or 1868. In 1891, J. C. Simpson erected a 50-ft.-diameter Guibal fan in Illinois. A large number of men were invited to see it, and the party became the occasion of the founding of the first Illinois Mining Institute.

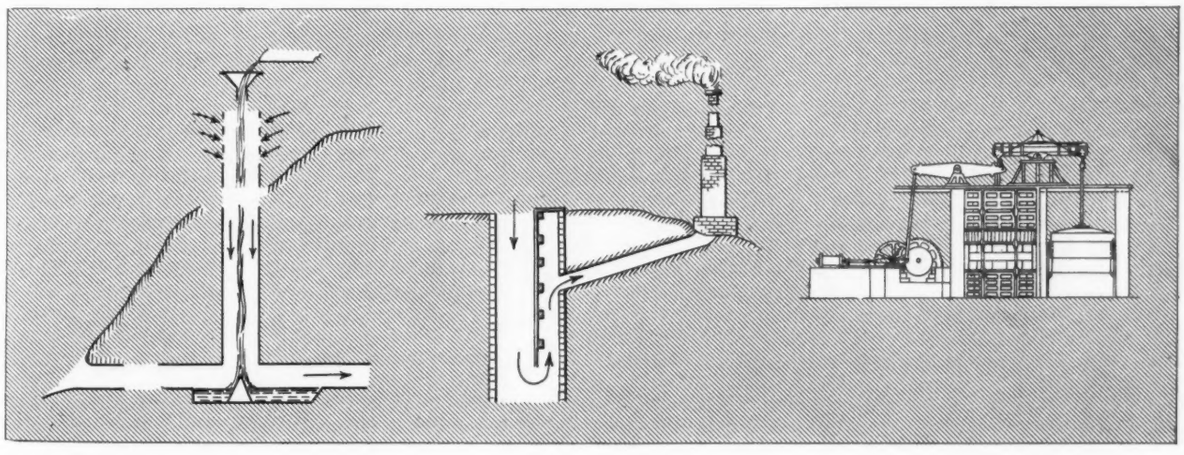
As late as twenty-five years ago, however, an immense number of furnaces were still in use at nongassy mines, and in such locations some are still in use today. There also were a number of disk fans of a host of different makers. Other fans in use were the Capell, Robinson, Jeffrey (single- and double-units), Stevens, Connellsville, Sirocco, Clifford-Capell, Stine centrifugal, Crawford & McCrimmon, Beard-Stine, Allis-Chalmers, Buffalo Forge, Sturtevant Multivane and Sullivan. All had scroll casings which were almost touched by the blades as they neared the base of the chimney, thus furnishing a fairly tight point of cut-off. The scroll provided space for more and more air from that point onward. Usually the blades curved forward, but a great difference of opinion developed among fan makers, and some of these fans are marvels of complex construction, bending in various directions and even offsetting in their progress toward the periphery and having additional blades that split the current into numerous streams where the distance between main blades became unduly large. As in the Guibal fans, most of these units had blades starting some distance from the shaft. The fans were of relatively high speed, of smaller diameter than those of earlier construction and frequently had needless scoops to drag air into the fan "eye." Stacks were made with *évasés* like those on Guibal fans, but usually much shorter and more flaring.

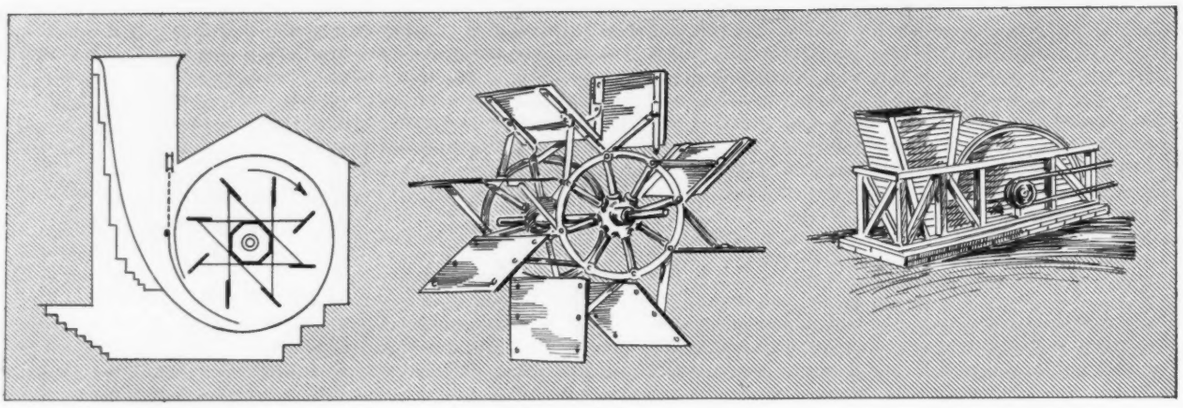
By 1911, therefore, ventilation practices had made considerable and diverse development. J. J. Atkinson, an Englishman, also had—in 1854 to 1863—promulgated his formulas of ventilation; E. Peclet, a Frenchman, had—in 1861—set down, in his "Traité de la Chaleur," his dictum that *évasés* should be well formed and flare no more than 6 or 7 deg. (otherwise, the air will become turbulent and may recirculate). D. Murgue (another Frenchman) had made charts showing the air speeds in various parts of roadways. The Pitot tube, anemometer, water gage, aeroid barometer, and wet- and dry-bulb thermometers had long been known and were already in use. The effect of low barometer on the escape of gas from gobs and goaves was well understood.

But, for many years thereafter, the study and practice of mine ventilation seemed to have traveled to its ultimate goal. Some fans, indeed, dropped out of use, but only minor improvements were made in the surviving forms and these were mostly mechanical and later electrical. For a while, electric current supply was unreliable, and the steam engine with slow fans held the field. All fan talk was of drives, bearings, standby engines, etc.; not of aerodynamics.

True, greater comformity to what was recognized as good practice came with passing years. Fans replaced furnaces somewhat rapidly; better overcasts and stoppings were erected, currents were better split, regulators were introduced; bleeders and boreholes were provided to carry off gas; fans of greater capacity and of higher water gage replaced units of

Water trompe **Furnace ventilation** **Struvé air pump**





Guibal fan **Paddle fan** **Early centrifugal**

lesser power; extensions of the mines were forecast and probable resistances calculated so that enough headings could be provided to carry the needed air.

Estimates were made of the cost of running fans with different mine resistances and of driving headings and sinking shafts to bring down the resistance to an economical figure. Shafts were sunk to advance fans to their work and to afford one-way ventilation from mine opening to shaft, so that returns could be converted into intakes, thus not only halving distance but doubling combined area of airways. Recognition was given to the fact that fans of equal efficiency and capacity, running at the same speed, will deliver different volumes of air to mines of unequal resistance.

However, the principles and mechanisms of fans were to remain for many years a closed book, except as to auxiliary and minor items. In fact, practices in the mines were then, and still remain, more in need of revision than fans, except at the better plants. Fans in many cases worked at extremely low efficiency, not because of their inherent lack of that quality but because the mines they had to ventilate were incapable, at the water gage generated by the fan, of passing the quantity of air the fan would deliver. It was found desirable for companies with many fans to move them around to mines having characteristics better suited to them than the mines at which they were working.

An early development was the introduction of auxiliary and booster fans. The former took a part of the air, diverted it into a pipe, usually of some flexible material, Flexoid or Ventube, but sometimes of steel, plain or galvanized, carried it to the working face and left it free to travel where it would.

Booster fans were used both here and abroad to help the main fan where that fan could not circulate enough air through the workings. They were used mostly in mines where the driving of headings involved the removal of rock and was therefore regarded as too costly to permit of the employment of many airways.

First among automatic mine doors was one constructed by N. K. Bowman in 1895. In the summer of 1898, the first automatic mine door made by the American Mine Door Co. was installed in the No. 3 Minglewood mine, James Mullins Coal Co., North Lawrence, Ohio, and operated until December, 1904. The motion of a treadle lifted a folding curtain from the bottom upward, and thus mules and cars could pass under it. The year 1914 saw an electrically operated door installed in the Seneca Shaft, Lehigh Valley Coal Co., Pittston, Pa., but mechanical operation has usually been preferred. Several double-door installations have been made for air-locking entire trips, notably one of the Allegheny-Pittsburgh Coal Co., at Springdale, Pa., in a tunnel under the Allegheny River, completed in 1921; another of the Bethlehem Mines Corporation between No. 41, Barrackville, and No. 42, Dakota, mines, installed in 1926; and a third provided at the mines of the Buckeye Coal Co., at Nemacolin, Pa., in 1932. The first two installations are operated mechanically and the latter electrically, using the electric eye.

Trouble with freezing shafts caused the introduction of the preheating of air. Perhaps the first provision of that kind in America was made in 1911 or 1912, at No. 8 Shaft, Hartshorne, Okla., of the Rock Island Improvement Co. (see Safety, p. 463). Another, prior to 1921, was at the shaft of the Norwood-White Coal Co., Moran, Iowa, which was heated by steam piping. Again, in 1925, the Raleigh-Wyoming Coal Co. preheated the air entering the Glen Rogers (W. Va.) mine with radiators using exhaust steam from the fan engine. Before 1926, the air in the intake shaft of Navajo No. 5 mine, of the Gallup-American Coal Co., Gallup, N. M. (759 ft. deep), was heated in like manner. Three York unit heaters, each delivering 1,890,000 B.t.u. per hour, with the heater air at 150 deg. F., were installed in Feb. 28, 1929, at the Pine Hill shaft, Pine Hill Coal Co., Lytle, Pa. On Nov. 30, 1929, two air heaters were installed at the Oak Hill shaft of the same company. At the 585-ft. shaft of the Pond Creek Pocahontas Co., Bartley, W. Va., Aerofin Corporation radiators have been provided to preheat the air. Seven units are installed for the auxiliary shaft.

Air-conditioning had been applied to prevent explosions, but in 1927 a plant was installed to lower the temperature of the air entering the mine of the Saxton Coal Mining Co., near Terre Haute, Ind., where heavy rock falls occurred in the summer months. The air is cooled by four sets of water sprays near the inlet of a blowing fan. Other Indiana plants installed in the past year include: Princeton Mining Co., Knox Consolidated Coal Corporation and Snow Hill Coal Corporation.

Despite its merits, the revolving door, such as is used in public buildings, has had only one application in coal mines of the United States. In January, 1927, the Consolidation Coal Co. introduced one at its Caretta (W. Va.) mine.

In the fall of 1928, the Monongah mine (Consolidation Coal Co.) installed a line of ten 19-in.-radius deflector-diffuser vanes on the diagonal of intersection between the head of the air shaft and the air drift to turn the air down and expand it with minimum resistance from 12-in. to

15¼-in. layers as it entered the shaft. Later vanes were installed at the bottom of the Valier shaft of the Valier Coal Co., but the ice formed in the winter fell and broke them. In the Springdale (Pa.) mine a deflector pyramid was installed at the foot of the air shaft late in 1935. It was built in the form of a truncated cone with slopes of 30 deg. and increased the flow 14 per cent. A similar conelike projection has been built up from the floor of the mine under a 760-ft. exhaust shaft sunk to ventilate mines Nos. 4 and 8 of the Union Pacific Coal Co., Rock Springs, Wyo.

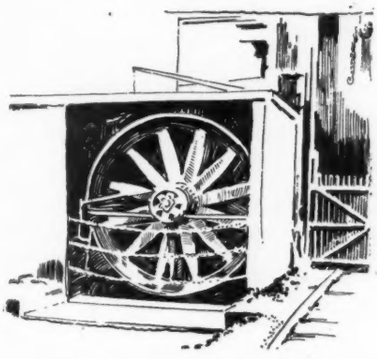
Not until 1931 did the American public get its interest aroused in the improvement of fans. That year saw the experiments of J. F. MacWilliams, electrical engineer, Pennsylvania Coal & Coke Corporation, Cresson, Pa., and the completion of development of the Aerovane fan. Mr. MacWilliams put in what he termed "turbulence eliminators," or vanes paralleling the scroll of varied length, to take off sections of the air delivered by the blades from their tips. He conceived that every blade shot air across the racing stream in the scroll, turning the current into a maelstrom. Only by use of vanes could the air travel in orderly manner. He emphasized the losses at the cut-off due to excess space at that point and pointed to the air recirculation in the *évasé* resulting from excessive flare, and imperfect cut-off. He also introduced venturi bends to bring the air to the fan.

About 1928, Archibald Saxe, chief engineer, Ellsworth Collieries Co., Ellsworth, Pa., made accurate air surveys of the mines with the aid of a Paulin altimeter, gaining much information as to ventilation losses. After his observations, surveys of like character were made in other mines.

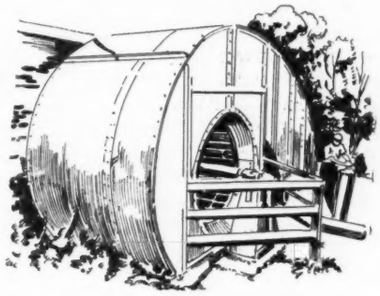
The first Aerovane fan (Jeffrey Manufacturing Co.) was installed about 1931 at one of the mines of the Republic Iron & Steel Co., Uniontown, Pa. An 8-ft.-diameter fan, it produced 89,300 cu.ft. per minute at 0.6-in. water gage. The Aerovane is said to retain an efficiency of 65 per cent or more, if run within 40 to 80 per cent of the maximum quantity of air, giving the fan a range of availability for varying length of airway and resistance. This fan later was made in two stages with vanes between them to bring the air into position for the second stage. Single-stage fans and double-stage fans give a water gage of 2 and 4 in. respectively.

Following the designs of Theodore Troller, who built a ventilator for use in the air tunnels constructed for the testing of aeroplanes, a fan was manufactured in the fall of 1933 by the Pittsburgh Coal Co., and several have been made and installed since. This fan is set in a venturi opening. It embodies only four blades, each of true propeller design. Static efficiencies in recent forms of this fan range up to 86 per cent. Its pressure increases rapidly with decreases in equivalent orifice, so that if the resistance increases, the water gage rises rapidly, making it possible to force more air into a resistant split by choking other splits in which ventilation is in excess of needs.

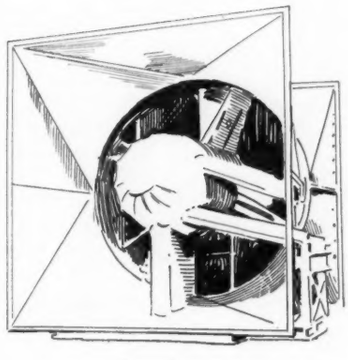
Disk fan



First U. S. propeller-type fan



Backward-bladed fan



Propeller fan

In 1923 and 1924, a backward-bladed fan was developed by the Robinson Ventilating Co. for use with the Davis air cleaner and, as it had desirable characteristics, was applied to a duct of the McKee Glass Co., November, 1925. A 6-ft. fan of 3 ft. 8 in. width was built on this principle for the Cambria Fuel Co. in April, 1927, belted to an electric motor. The Robinson Ventilating Co. and the Goodman Manufacturing Co. have placed fans of this type at many mines.

A light propeller fan, the Charavay, introduced in 1933 at the mine of the Amherst Coal Co., Amherstdale, W. Va., has six propeller half blades which travel at from 300 to 700 r.p.m. and in a circle of 76- to 94-in. diameter, overlapping the ring to prevent recirculation. By changing blades the fan can be adjusted to give increased capacity. Several Charavay fans have been installed by the Hartzell Propeller Fan Co. These fans have a shaft slung from the ring and driven by belt from a motor at one side.

A fan with an overhung wheel is being erected by the Glen Alden Coal Co. at the Askam Shaft, Nanticoke, Pa., to give 150,000 cu.ft. per minute at 3-in. water gage in summer and 150,000 cu.ft. per minute at 4-in. water gage in the winter, being run at 352 r.p.m. and 382 r.p.m. respectively. This American Blower will be driven by a wound-rotor motor, and a standby duplicate by a gasoline engine. The shaft is 20 ft. in diameter and 2,050 ft. deep.

With the introduction of improvements in fan construction, fans could be driven faster. For this reason they have been growing smaller while they have been increasing in capacity. The slow-moving, mammoth fans are of their own generation. America has pretty definitely gone to smaller fans and higher speeds with electrical drive.

MINE POWER AND ELECTRIFICATION

APPLICATION OF power to coal-mining operations goes back less than 100 years in the United States, in which time, particularly in the last quarter of a century, it has spread into all underground and surface activities from cutting, drilling and loading at the face to spraying the coal with a dust-allaying oil or packing it into bags or boxes at the shipping point. Out of this growth in power use have come two major benefits: elimination of many of the arduous tasks of the miner and a broadening of the opportunities for the economical performance of almost all mining activities.

Miner's Work Lightened

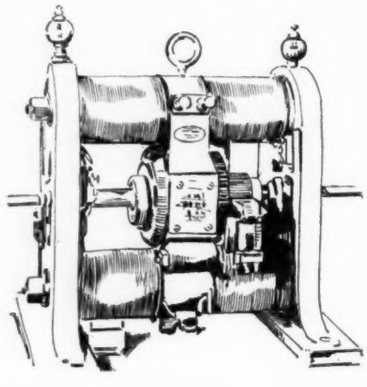
The miner of today is relieved, for example, of the exhausting and time-consuming labor of undercutting by the use of power. Moreover, power makes it possible to move 1,000 or more cars per shift over a 5-mile haul from the face to the tipple—an impossible task with hand tramming or even animal haulage under present-day conditions. Also, it is inconceivable, to cite another instance, that the modern preparation plant producing 7,000 or 8,000 tons in seven hours could be operated with hand labor.

Steam was challenged by electricity nearly 50 years ago, and by 1911 this new agent was being applied with increasing rapidity to the operation of cutting machines and locomotives and in individual drives for pumps, hoists and, in some cases, anthracite breaker machinery. At that time, direct current from a mine-mouth generating plant was meeting its first real competition from alternating current supplied by a central generating station or purchased from a public-service company. Now, in many 1936 mines, a.c. power operates loaders and mining machines at the face or is brought to within 1,000 ft., where a portable substation converts it to Iron Co. in 1870. Smoke, gases and direct current. Only its advantages for locomotives have helped direct current hold its position against a.c.

Newcomen's pumping engine, used in dewatering British mines in 1710, was the first application of steam to coal mining. Incidentally it immediately broadened the scope of mining operations by making it possible to remove water economically and thus work a much larger pit. The records fail to show the first application in coal mining in the United States, but Bast used steam to drive the rolls and screens at the forerunner of the present anthracite breaker, erected near Minersville, Pa., in 1844. The "Lykens Valley," first steam locomotive used by an American coal company, started work on an outside haul in 1848.

Steam hoists were being used in 1849, following the development of a satisfactory wire rope subsequent to the manufacture of the first wire rope about 1831 to replace vegetable fiber. Apparent loss of the art of wire-rope manufacture for nearly 1,800 years was revealed by the excavations in the ruins of Pompeii, where a piece of bronze rope built up of strands of fifteen wires each was found. Underground use of steam locomotives probably began with the purchase of two 7-ton machines by the Wilkes-Barre Coal &

One of the earliest Gramme dynamos, out of which grew electricity's phenomenal advance



fire hazards, however, have resulted in the virtual elimination of steam locomotives from underground workings, but they still are the principal means of outside transportation at anthracite operations. In the operation of hoists, fans, preparation-plant equipment, etc., the steam engine is now the exception. Pending further developments, steam's present place in coal mining is clearly defined as the medium of energy transformation in the electrical generating plant.

Although some pneumatic drills may have been used earlier at anthracite operations, commercial application of compressed air to mine service began with the development of the Harrison puncher and Jeffrey (Lechner) breast machine in 1877. Later (p. 408 of this issue), compressed air was used to operate the first horn- and chain-type longwall and shortwall cutters. In 1882, the first compressed-air locomotive (Baldwin) was installed at the Old Eagle colliery, W. H. Brown's Sons, near Brownsville, Pa. Weight was 8 tons; track gage, 43½ in.; and charging pressure, 400 lb. per square inch.

Air Meets Electricity

Compressed air had just gotten a good start when electricity challenged it in 1888. Up to about 1911, however, both ran about neck and neck. Thereafter, air began to drop back, although its inherent safety advantages in gaseous mines, adaptability to percussion tools and aid in ventilation have kept it in the running. A number of compressed-air locomotives still are in service, particularly in the anthracite region, but the major field for compressed air at present is operation of pneumatic tools for coal or coal and rock work, and shaker conveyors. Compressed-air chain-type cutters are now used at only two large-capacity mines (Jamison Coal Co., Farmington, W. Va.).

Stationary compressors and pipeline distribution at 100 lb. per square inch is the practice at most anthracite mines, where the largest unit, driven by a 1,000-hp. synchronous motor, has a capacity of 5,000 c.f.m. Stationary compressors are used at a few bituminous mines, principally those with air-driven shaker conveyors, but nearly all have one or more portable electric units with capacities of 75 to 150 c.f.m.

Although Thomas Davenport demonstrated a small electric locomotive powered by a reciprocating motor at Springfield, Mass., in 1835, using a primary battery for power, it was not until 1870, when Gramme

produced the drum-wound self-excited dynamo, that electric power started its phenomenal advance. Edison's incandescent lamp and the multiple system of generation and distribution in 1879 were the next important steps. By 1884, arc lamps were being used to light streets and electric-motor-driven street cars were in the experimental stage. Coincident with the first really modern street railway system, installed at Richmond, Va., by Frank Sprague, 1887, came the first commercial coal-mine electrical installations. In that year, the Hillside Coal & Iron Co., in the Northern anthracite field, installed a Thomson-Houston arc-lighting plant and the Lykens Valley Coal Co. placed in service in the Southern field the first electric locomotive, designed by W. M. Slesinger, of Philadelphia, in a United States coal mine.

From 1888, when electrically operated cutters were offered, until 1900, d.c. power plants held the field. A typical installation consisted of two hand-fired h.r.t. boilers and two 150-kw. generators belt-driven by non-condensing slide-valve engines. Voltages were 220 and 550, the latter predominating. A few of these 1888-1900 generators still are in service.

D.C. Gets Competitor

After 1886, however, when William Stanley started up the first transformers and parallel-connected a.c. system in America, at Great Barrington, Mass., direct current had a competitor. A Siemens alternator was imported to Pittsburgh in 1885 by Westinghouse, which acquired patents for a.c. induction motors in 1888. But it was not until 1901 that the inherent difficulties of long-distance d.c. transmission resulted in the first underground use of a.c. In that year, the General Electric Co. built an a.c. plant at Ehrenfeld, Pa., for the Webster Coal & Coke Co.

Included in the Ehrenfeld installation were two 150-kw. double-current generators supplying d.c. at 275 volts and three-phase 25-cycle a.c. at 169 volts. Generators were of the same design as 250-volt converters, had extended shafts for belt pulleys and were intended for later use as substation units when alternators were substituted in the power plant. The a.c. current was stepped up to 5,600 volts for transmission through a 3-conductor No. 6 gage rubber-insulated cable with lead sheath to an underground substation containing a 275-volt converter and suitable transformers. In the period between the Ehrenfeld plant and 1910-11, characterized by increased use of steam turbines, a.c. gradually displaced d.c. for stationary drives, including some underground pumps. Hard on the heels of the first 2,000-kw. Parsons turbine at Hartford, Conn., in 1901, came the steam turbine in a coal-mine power plant—Delaware, Lackawanna & Western Ry., Hampton, Pa., in 1903.

Dispatchers now vie with limiting devices in the control of demand peaks

Replacement of individual d.c. plants with central a.c. plants and transmission lines was an outstanding feature of 1910-14 developments. Mostly, the new plants were equipped with stoker-fired water-tube boilers and condensing turbines, and were 60 cycles, as compared with 25, 50 and 133 cycles earlier. At the same time, however, the upward swing in public-utility service to coal mines began as a result of increasing difficulties in the maintenance of proper voltage due to the lengthening of distances between the mine power plant and the working territories, in addition to costly generation growing out of hand-firing with its high labor costs and low combustion efficiency, inadequate feed-water treatment and, as a rule, use of marketable mine-run coal.

A limited revival in the construction of mine power plants has marked developments since 1930. In several of the smaller of these plants the alternators are driven by non-condensing uni-flow engines or geared turbines, reflecting the use of track cleanings, picking-table refuse, high-ash slack or other unmarketable products as fuel. In practically every case, however, the boilers are equipped with stokers or pulverized-coal firing equipment and modern control devices.

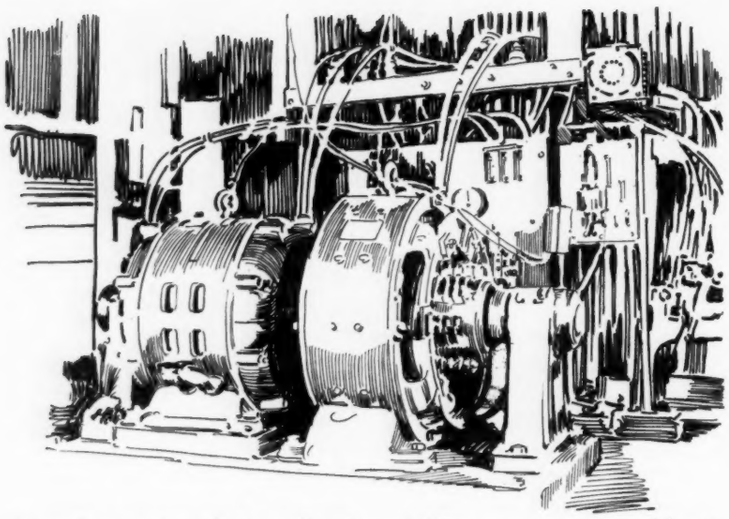
On the basis of B.t.u. content, oil and gas always have been higher priced than coal. Consequently, internal-combustion engines never have been used extensively for mine power (a 1925 survey showed 24 with a total horsepower of 2,567). In 1930, the Price Hill (W. Va.) Colliery Co. gave up purchased power and built a diesel generating plant with four units totaling 1,400 hp., later increasing capacity a third by two additional units.

Between 1895 and 1900 a number of small gasoline engines were installed at mines for miscellaneous duties such as driving pumps, fans, etc. In 1898 the gasoline locomotive entered the picture and, although their use was never general, a few still are in service.

Standby Units Necessary

With the advent of purchased power came the necessity for standby power units for fans at gaseous mines, for which gasoline engines have been favored. Up to 1920, single-cylinder engines with mechanical-drive connections to the fans were the regular practice. Then came the multiple-cylinder high-speed marine or automobile engine directly connected to a generator which could, in an emergency, run the fan, provide lights and perhaps operate a hoist. Many of these 100- to 300-hp. units were installed between 1920 and 1927, but the necessity for standby units decreased as power companies perfected their service.

"Complete" electrification of mines began to gain ground about 1911 and accelerated with the rise in purchased-power use in later years. At that time, complete electrification was regarded by some as only the replacement of steam engines by motors, even though miners were undercutting by picks and stock was



Manual substation of the earlier days—100-kw. m.g. set, open wiring to switchboard

used for gathering. After 1920 and prior to the large-scale use of mechanical-loading equipment, complete electrification was generally understood to mean that motors were applied to cutting, drilling, gathering, hauling, hoisting, ventilation, pumping and preparation.

When preparation, generally speaking, meant hand-picking and screening, completely electrified mines usually consumed 3 and 4 kw.-hr. per ton, although at very wet and gaseous mines the figure mounted to 15 to 20 kw.-hr. Mobile-type loaders have added ¼ to 1 kw.-hr. per ton; modern cleaning plants, 1 to 2 kw.-hr. Thus 6.5 kw.-hr. per ton is a representative figure for the fully electrified mine of 1936 with moderate to small hoisting, pumping and ventilation loads. At anthracite mines, figures of 20 to 30 kw.-hr. per ton are common, even where no cutting machines or mechanical loaders are in use.

Lack of metering equipment and the difficulty of accurately computing power costs at the typical individual plant failed to encourage economical utilization in the earlier days. But the purchased-power invoice plainly indicated the advantages of reducing average demand and energy consumption, and at some mines sufficient economies were effected to balance the normal increase growing out of extension of electrification.

Even the early power contracts included demand charges, but not until after 1920 did the industry turn extensively to demand limiting by automatically opening the circuits and employing dispatcher control of pumping and main haulage loads to avoid undue demand burdens, particularly during periods of slack running time. Early limiters consisting of series relays which opened certain circuits when the total load reached a certain amperage were not, however, highly effective because they operated without regard to synchronism with the demand period of the power company's meter.

In 1925 came the practice of coal companies purchasing a demand meter and equipping it with a contact to light a signal lamp when a predetermined demand was exceeded, keeping this demand meter in period synchronism with the power-company meter. Guided by the signal lamp and the pointer of the demand meter —mounted on his platform—the hoistman suspended hoisting or perhaps opened one of the power circuits to limit demand until the end of the period.

Commercial demand limiters, of which the first was the Edmoore "Limitator," appeared at coal mines in 1928. Many were installed in the next five years, although the rapid increase in mechanical loading with its demand for uninterrupted service kept many companies from installing any device that would interfere with important circuits. Soon after the installation of the first commercial limiters, objections, such as interruption of the circuit too late in the period to be of any practical effect, were discovered, and as a result various devices were added to effect improvements, later incorporated in commercial types, such as the General Electric unit of 1933 embodying all the features that experience has demonstrated as necessary.

Employment of dispatchers to regulate haulage, although not new, began to gain ground in 1927, and reducing demand by preventing simultaneous hard pulls by several locomotives became a common practice. By 1932, certain companies had installed demand metering and limiting equipment in dispatchers' offices so that operation of main-line units could be timed with due regard to demand accumulation and demand-period progress. Thus, 1936 finds many demand limiters in use, particularly by smaller companies. In most cases, limiting is automatic but in the most elaborate installations there is a continuation of automatic and manual operations, with the instruments and controls installed on the hoistman's platform or in the dispatcher's office.

The economic urge to reduce power cost starting about 1921 also brought about a general trend toward central metering to secure the diversity advantage on demand charges and place a high percentage of the energy billing in the lower-rate brackets. Central metering required the coal company to invest in transmission lines, but the investment usually was returned in savings in a few years. An early example of the change to central metering, which reduced power bills 19 per cent, was the Keystone Coal & Coke Co., Pennsylvania, in 1923.

Power Factor Crops Up

Power-factor clauses were included in the early rate schedules of a few power companies, followed by a gradual spread in their adoption until today the large mines and most of the centrally metered groups operate on schedules providing a premium for high and a penalty for low power factor. As a result, selection of substation equipment has been modified, development of high-torque self-starting synchronous motors has been accelerated and attention has been focused on static condensers, or capacitors.

Rotary converters probably antedated motor generators as substation units, and as the early m.g. sets included induction motors, mines originally had no equipment with which to improve power factor. After 1908, however, a number of synchronous m.g. sets were installed, giving those mines a certain degree of power-factor control, and in that year the Glen Alden Coal Co. installed two synchronous motors on anthracite breaker pumps. Next, this motor type was applied successively to stationary compressors, mine pumps and fans.

In 1911, the McKell Coal & Coke

Co., southern West Virginia, installed the first synchronous fan motor, a Westinghouse 250-hp. 25-cycle 6,300-volt unit described as having "induction motor windings on the rotor." The drive connection was a silent chain. Beginning in 1922, the number of mine pumps driven by synchronous motors began to increase rapidly, mostly in the anthracite region, where a survey early in 1935 showed a total of 67 motors aggregating 25,500 hp. in this service. A number of synchronous motors have been installed on anthracite and bituminous fans since 1928. Power-factor correction by the use of synchronous condensers has not been favored by coal companies because friction and windage reduce the net gain from the leading current, although a few installations have been made.

Capacitors Come In

Capacitors did not begin to make headway until 1932, although a unit was installed at the anthracite operation of the Richmondale Coal Co. in 1925, the forerunner of a number by the larger anthracite and bituminous companies in late years, most of which paid for themselves in nine months to three years.

While synchronous converters were used as substation units in connection with some of the earlier a.c. generating plants, such as those at Hampton and Ehrenfeld, they had to meet from the beginning the competition of the motor-generator set with its advantages of d.c. voltage control and — later — power-factor control. Converters still are being installed, but motor-generator sets appear to have the widest application as a result of the opinion of the majority of mining electrical engineers that voltage and power-factor control and elimination of transformers overbalance the higher losses.

Although the Ehrenfeld station was located underground, surface installations in the period 1910–20 —the substation decade—far outnumbered the underground type. Today, however, there is a definite swing back to underground stations, growing out of the necessity for better d.c. voltage regulation in mechanical loading and concentrated, rapid mining. While a 400-kw. portable substation on a railroad car was used in developing new mines in 1913, it was not until about 1926 that the portability feature was included in an underground substation. In that year, the Union Colliery Co., Dowell, Ill., installed one of the first portable units, consisting of a converter with trucks, which are removed at a new location, accompanied by a transformer-control unit permanently mounted on a wheeled truck.

Additional units in which both the conversion and transformer-control units are permanently mounted on trucks have since been installed at Dowell. Other early users were the Dresser mine, Walter Bledsoe & Co., Terre Haute, Ind., and the Wildwood (Pa.) mine, Butler Consolidated Coal Co. About a dozen bituminous mines now use portable substations. There are none, available information indicates, in the anthracite region.

The first stage in making substations automatic was the installation, prior to 1916, of d.c. reclosing feeder breakers developed by the Automatic Reclosing Circuit Breaker Co. The first full-automatic substation went to Alabama in 1920, when the Mt. Carmel Coal Co. installed at its Cordova mine, near Birmingham, a 150-kw. 275-volt m.g. set equipped with a reclosing d.c. breaker and Cutler-Hammer magnetic switches for self-starting.

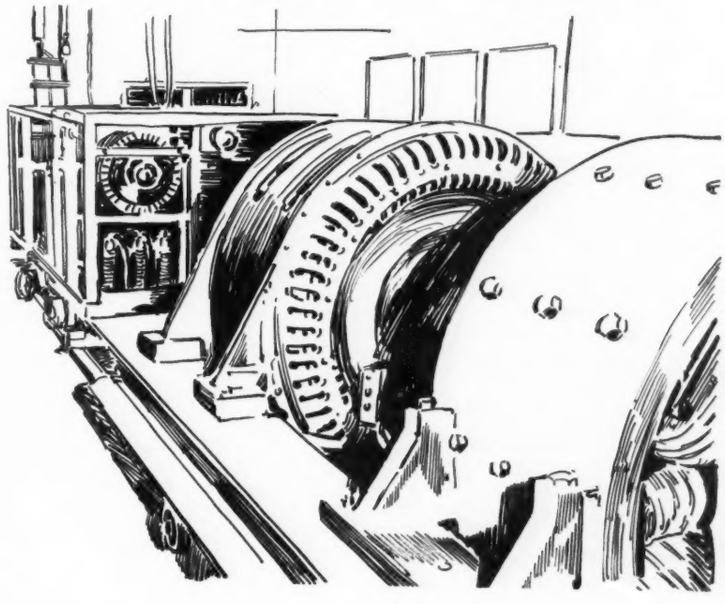
Bearing thermostats and certain other protective features of the modern full-automatic stations were not included in the Cordova installation, but in January, 1921, the full-automatic underground station installed by the Lincoln Coal Co., Nanty-Glo, Pa. (200-kw. synchronous m.g. set and Westinghouse automatic starting controls), was equipped with thermostatic protection. And also in 1921, the Lehigh Valley Coal Co. put in service a full-automatic 275-volt converter set at the Drifton anthracite colliery, started and stopped from a pushbutton station one-half mile away.

Telephone control of an automatic substation, by which starting, stopping and checking of operation could be accomplished by dialing certain numbers on any plant telephone, was put in effect in 1926 at the Wolfpit (Ky.) mine of the McKinney Steel Co. In addition to the same type of control, remote metering was included in a full-automatic installation of two 300-kw. m.g. sets at the Nemacolin (Pa.) mine, Buckeye Coal Co., in 1928.

By September, 1922, 50 full-automatic substations were in service, the forerunner of great activity up to 1927, in which period numerous refinements to simplify equipment, provide protection against all emergencies and increase reliability were developed. In April, 1927, the Rectox rectifier for insuring correct polarity without the use of any transfer equipment was first applied by Westinghouse to a full-automatic synchronous converter station of the North-East Coal Co., Paintsville, Ky. Today, the full-automatic substation is standard equipment and manually controlled stations are restricted largely to locations where a man normally is engaged in other work near by.

Although termed fully automatic, few motor-generator stations as yet merit this term from the power-factor regulation standpoint, as such regulation still is the exception rather

Modern portable substation—400-kw. m.g. set automatically controlled, on one truck; control equipment on another



than the rule, inasmuch as many electrical engineers are satisfied with the degree of regulation obtained by compounding the d.c. generator, which has a limited effect on the synchronous-motor field current. Two installations of automatic equipment to regulate the field current of the synchronous motor in relation to the d.c. load were reported to be working in Pennsylvania in 1924.

In 1927, Sherman Melton, electrical engineer, West Kentucky Coal Co., patented and installed on a m.g. set at the Shamrock mine an automatic power-factor regulator employing an auxiliary exciter to change the motor field in accordance with d.c. load. In 1928, this scheme was adapted for several substations of other companies where exciters already were in use and a change of connections was all that was necessary. Amherst Fuel Co., Logan County, West Virginia, installed on July 1, 1928, a regulator which used series d.c. load relays to operate a contactor that cut in and out four steps of synchronous-motor field resistance.

Rectifier Used in 1927

Use of a mercury-arc rectifier to furnish d.c. mine power dates back to 1927, when the Appalachian Power Co. installed a 300-kw. 550-volt Brown-Boveri tank-type unit with automatic control in its substation at the Rolfe mine, Pocahontas Fuel Co., Worth, W. Va. This rectifier—still in service—replaced a synchronous m.g. set and raised station efficiency from 50 to 85 per cent. Available records show an average annual maintenance cost of $79.60, compared with $198.20 for automatic motor generators and $255.50 for automatic converters.

In 1930, the Glen Alden Coal Co. operated an experimental 275-volt unit for a few months at the Storrs anthracite colliery. The Ignitron mercury-arc rectifier with individual tubes instead of a tank was offered by Westinghouse in 1936, and at least two other manufacturers are now featuring rectifiers, one of which recently sold two 600-kw. 575-volt units to a bituminous operation in the Pittsburgh area. Voltage control by means of grids is a recent rectifier improvement.

Twenty-five years ago, electrical distribution was based primarily on the use of d.c. circuits of 2/0 or 4/0 bare wire, round or figure 8 section, with 30-lb. or lighter track rails bonded with 2/0 channel-pin or compressed-terminal bonds for a return. A.c. transmission lines and underground cables had been installed by only a few companies, although a.c. transmission voltages already had been raised to 22,000—at least the Consolidation Coal Co. had constructed pole lines for that voltage. Other a.c. voltages in use were 2,200, 4,150, 5,600 and 16,000.

Operations today are marked by distribution of much larger quantities of direct current to remote points underground for concentrated mechanical mining and the development of more economical and reliable cable practices for boreholes, shafts and underground passageways.

The second anthracite mine-locomotive installation (Thomson-Houston, 40 hp.) at a Hillside Coal & Iron property, 1889, received power from a 1/0 hard-drawn wire. Until about 1926, when the savings possibilities in the larger size began to gain strength, the largest size in general use was the 4/0, with a substantial proportion of 2/0, particularly in the earlier days. New mines opened and old mines modernized in 1927 and later have largely been equipped with 6/0 wire, which, in the standard type, has about 59 per cent more area than 4/0. It should be noted, however, that the so-called 6/0 wire as now manufactured has an area of 350,000 circ.mils, as compared to 336,457 for the regular 6/0 type, and lately is being more properly termed "350,000" trolley wire. Figure 8 wire was in common use until 1920, when the greater ease in hanging and moving attracted attention to the grooved section.

Maximum size of stranded feeders for d.c. circuits has increased step by step in the last twenty years from 500,000 to 2,000,000 circ.mils. As a rule, 1,000,000 circ.mils is the maximum size underground and 2,000,000 circ.mils in shafts and boreholes. Two devices—the combination feeder sling and trolley clamp and the combination feeder-wire clamp—brought out about fifteen years ago and still yidely used were the forerunners of the increase in trolley-wire size to 6/0 and had a material effect in hastening the necessary reinforcement of haulage circuits.

Pin-driven and compressed-terminal bonds, both antedating 1890, vied for preference until about 1918 (with the compressed-terminal type generally preferred for main-line work), when the arc-welded bond began to attract followers. Soldered bonds, another early type, soon passed out of the picture. The first of the electric type was based on welding the copper to the rail by a carbon arc. Next was a steel-terminal bond used with a steel electrode, and third came the practice of welding the copper to the rail with a copper-alloy electrode, now the most widely used. Gas-welding, another practice, was never widely employed in bonding.

Short bonds welded to the head of the rail or the edge of the base were used at a few mines as early as 1919, but, although low in cost and resistance, suffered under the handicap of lower track standards. Rail joints were not rigid enough to prevent undue flexing and, also, it was common practice to operate locomotive tires with false flanges of sufficient magnitude to damage railhead bonds. Use of short bonds underwent a revival after 1930, however, the Island Creek Coal Co., for example, standardizing on this type in 1933.

Welding Track Adopted

Welded track as a means of securing rigid joints and eliminating bonds was tried before 1920, but did not begin to make headway until after 1933, when the Consolidated Coal Co. began experiments on main-line track at its New Monarch operation, Herrin, Ill., followed by the adoption of welding as a standard practice. Under the Consolidated system (July, 1936, *Coal Age*, pp. 275-77), the angle bars are retained. Cost of a welded joint, materials and labor, is 68c., compared to $1.00 for bonding with 28-in. 4/0 copper-electrode-welded bonds.

Several other companies have adopted arc-welding of rails on main lines in the last two years. Beginning in 1935, the Hanna Coal Co., Ohio, started welding with the Thermit process, in which angle bars are eliminated and a steel insert is used. Track thus welded costs not over $50 per 1,000 ft. more than bolted and bonded track.

Use of underground cables for a.c. circuits began with the Ehrenfeld installation, noted above, in 1901. In 1911, the McKell Coal & Coke Co., southern West Virginia, installed a No. 4 three-conductor 10,000-volt varnished-cambric-insulated lead-sheathed wire-armored cable in a 350-ft. borehole cased with 6-in. pipe to feed an underground substation. In the interim between the Ehrenfeld and McKell installations, only a few a.c. cables had been used underground or in boreholes, but a number of wire-armored cables had been installed in shafts and slopes to feed pumps.

Lead and steel protection was the

rule until about 1930, when cables without metallic protection came into common, although not exclusive, use. Non-metallic cables, however, go back at least to 1914, when G. M. Kennedy, Lehigh Navigation Coal Co., Lansford, Pa., installed, in several boreholes, d.c. single-conductor cables with rubber insulation protected by rubber braid. Improvements in rubber compounds, braids and impregnating agents in succeeding years have made non-metallic cables practical for all types of mine service and, particularly in high-voltage service underground, elimination of grounding on metallic armor has been found a major advantage.

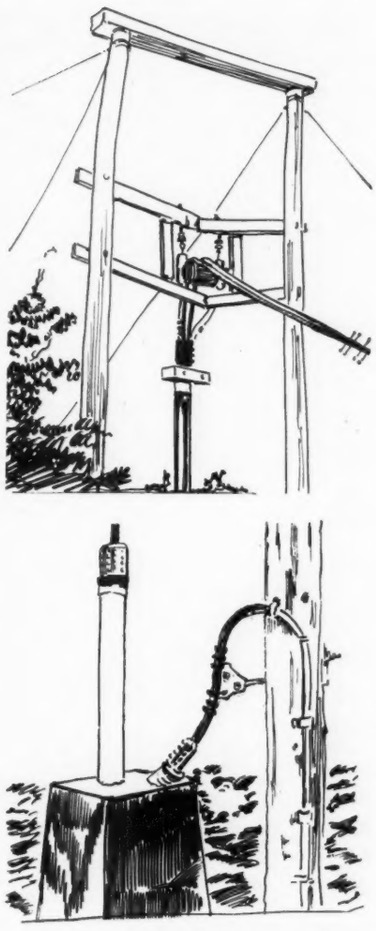
Decreased weight through the elimination of lead and armor also has made practicable, at depths up to 1,000 ft., suspension of the cable by the conductor alone. Beginning four years ago, the Old Ben Coal Corporation, Illinois, installed several concentric 2,000,000-circ.mil cables suspended to 500-ft. depths by the copper conductors. In 1935, the Pond Creek Pocahontas Co., Bartley, W. Va., suspended a single-conductor 1,500,000-circ.mil cable, insulated with Anhydrex water-resistant rubber (1930) and without armor, in an 835-ft. borehole, using the conductor.

Cables Hung in Boreholes

During 1935 and 1936, the Susquehanna Collieries Co., anthracite, and the Pocahontas Fuel Co., bituminous, each installed several Anaconda non-metallic-cover copper cables with factory-applied connectors for vertical suspension in shafts and boreholes. The longest, a 723-ft. 1,500-000-circ.mil single-conductor 550-volt cable, Jenkinjones mine, Pocahontas Fuel Co., has a factor of safety of 12, according to the manufacturer's rating.

An 880-ft. cable installed three years ago in the No. 12 shaft, Greenwood colliery, Lehigh Navigation Coal Co., remains the largest of its type at a coal mine, however. Its specifications are: three conductors, 800,000 circ.mils, 11/64-in. 30-per-cent Amerite rubber insulation, rubber-filled tape, conductors cabled together with jute fillers, one rubber-filled tape to form jacket, jute and No. 4 B.w.g. galvanized wire armor, heavily asphalted.

Along mine passageways, d.c. feeder cables, usually bare but in many cases insulated, always are suspended from the roof or rib. For a.c., however, trench installations still are favored by many companies, especially if the roof is weak or unreliable.



Contrasts in borehole suspensions: Above, 1,000,000-circ.mil cables rest on wooden spool; below, modern suspension for 1,500,000-circ.mil positive and negative circuits in 836-ft. borehole

Electric hoisting goes back to about 1890, as soon after that date d.c. motors were applied to small coal hoists, but it was not until after 1900 that it was adopted to any notable extent. Extensive use of this equipment awaited the central-generating-plant trend that became evident in 1910 and the purchased power trend starting in 1911. Wound-rotor motors featured the first large installations.

In 1912, Carl Scholz, then in charge of the Rock Island Ry. mines, installed a 300-hp. 2,300-volt shaft hoist at Dallas, Iowa, one of the first examples of the use of contactor controls and one of the few in which the operating station was placed at the dump in the tipple. A Vulcan hoist powered by a 700-hp. 2,300-volt 25-cycle wound-rotor induction motor controlled by a liquid rheostat instead of a grid resistance was installed by the Woodward Iron Co., Alabama, in 1913.

An electric hoist employing the Ilgner-Ward Leonard system was installed at the No. 11 mine, Old Ben Coal Corporation, Christopher, Ill., in 1912, by A. W. Spaht, electrical engineer. Peak loads on the line were reduced by a regulator automatically actuating a liquid rheostat to insert resistance in the induction-motor secondary, thus allowing the flywheel to give up some of its energy. Control of the d.c. hoist motor was effected without rheostatic losses by field regulation of the generator voltage.

Still the largest at a coal mine, an Ilgner-Ward Leonard hoist driven by two 2,000-hp. d.c. motors went into full-scale operation at the New Orient mine, Chicago, Wilmington & Franklin Coal Co., Illinois, in 1925. Departing from previous practice, Carl Lee, electrical engineer, Peabody Coal Co., installed a motor-generator-d.c. hoist, less flywheel and with a 1,100-kva. synchronous rather than an induction motor driving the generator, at Mine No. 53, Springfield, Ill., in 1929. Ward Leonard control was included, but line-load balancing was not considered necessary, thus making it possible to eliminate the flywheel and use a synchronous motor, lowering the cost and increasing power-utilization efficiency.

Induction Motors Rise

With improvement in power-company service has come less need for load balancing, with the result that the induction-motor drive — far cheaper than a motor generator and d.c. motor—has been extended to include sizes up to 1,250 hp. and is now the most widely favored type. Grid resistances have finally proved their superiority over liquid-rheostat controls.

Large hoist installations have fallen off in late years with the decrease in number of new shaft mines opened plus extension of slopes with belt conveyors to greater depths. Modern practice is exemplified at No. 14 shaft hoist, Tamaqua colliery, Lehigh Navigation Coal Co., installed in 1930. This geared hoist is driven by a Westinghouse 1,200-hp. 2,300-volt 293-r.p.m. wound-rotor induction motor. Primary contactors of the controls are actuated by air cylinders with solenoid-controlled valves, and the secondary resistance is of the grid type. Lehigh Navigation installed its first electro-pneumatic hoist controls in 1925.

Fan drives, both motors and mechanical connections to the fans, probably have been the subject of as

much study as any other phase of mine electrification. Early installation soon after 1890 was based on the use of the d.c. motor and long-center flat belt. Except for higher maintenance, the d.c. motor was quite satisfactory in that it permitted a degree of speed regulation without high rheostatic losses. But when a.c. primary power came into general use after 1911 it brought with it the a.c. motor for fans, initiating the campaign to obtain speed variations without the high rheostatic losses of the speed control for the wound-rotor induction motor.

Originally the squirrel-cage motor was satisfactory only on small fans without a high starting torque. With that type motor, speed changes required a two-speed model, one of which was installed on a mine fan in 1913 by the Keystone Coal Co. The common installation then, however, was wound-rotor induction motor, one in 1913 consisting of a 300-hp. 2,300-volt motor connected to the fan by a rope drive.

The commutator-type brush-shifting variable-speed induction motor was introduced in western Pennsylvania mines in 1914, followed later by several Sherbius-system installations. Both were satisfactory from the variable-speed standpoint, but high first and maintenance costs, particularly of the brush-shifting motor, prevented extensive adoption.

Although the latest work in fan drives revolves around the synchronous motor, the first application goes back to the McKell Coal & Coke installation cited above, made in 1911. Not until 1924 were there many other synchronous-motor fan drives, and for the most part, beginning in that year, magnetic clutches were used to allow the motor to pull into synchronism before the fan came up to full speed. Two 75-hp. installations of this type, using flat-belt drives, were made by the George F. Lee Coal Co., Avondale, Pa., in 1925, followed by another installation by the Buck Run Coal Co., Minersville, Pa.

Later, a few fans were powered by the super-synchronous motor with bearing-mounted stator, which is allowed to rotate during starting and then is stopped by a hand brake, effecting clutch acceleration of the load after the motor has pulled into synchronism. Five such drives are operated by the Glen Alden Coal Co. in the anthracite region.

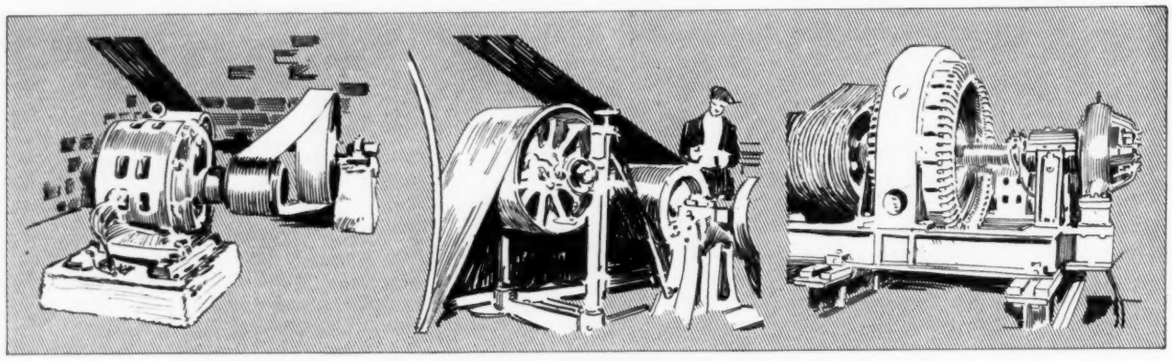
Although standard synchronous motors with higher pull-in torque were announced in 1926, these failed in some instances to start heavy fans, which led to the use of doors in a few cases to choke the air current while starting, such as the 1928 fan (9x3½ ft.) driven by a 175-hp. synchronous motor at the Maben (Ala.) mine, Sloss-Sheffield Steel & Iron Co. In the same year, a 500-hp. synchronous motor with built-in magnetic clutch replaced the original induction motor at New Orient.

Applying synchronous motors to old steam fans—in most cases, larger, heavier and less efficient than modern types—sometimes entails starting difficulties. Failure to pull in with certainty led the Lehigh Valley Coal Co., anthracite, to use a Bethlehem snub starter with a 125-hp. motor in 1931.

Improvements in design, however, have made available synchronous motors with a sufficiently high pull-in torque for any fan drives without auxiliary devices. Consequently, a number of large fans, beginning in 1933, have been thus equipped. The largest synchronous fan motor was installed in 1934 to replace a steam engine at the No. 1 mine, Pond Creek Pocahontas Co., Bartley, W. Va. This 600-hp. General Electric 0.8 power-factor-leading motor is started across the line by a semi-automatic panel. Twenty 1½-in. wide V-belts constitute the drive connection. Power-factor-correction savings aggregate $1,000 per month.

Motors have been directly connected to fans in only a few cases, as that arrangement usually requires a lower-speed higher-cost motor and prevents changing drive ratio to vary fan speed. An outstanding example is the 350-hp. 28-pole 257-r.p.m. wound-rotor induction motor directly connected to a 11½x7-ft. fan in 1929 at the Federal No. 1 mine, Grant Town, W. Va.

A quarter of a century ago, when few large fans were motor-driven, long-center flat-belt drives were the usual and rope and silent-chain drives the unusual. Rope drives gained but little headway, while the silent chain has had a consistent, although small, following to the present day. In 1919, a new fan at the Dehue (W. Va.) mine was equipped with a short-center flat-belt adjustable-idler connection to a 150-hp. induction motor. Although a few idlers had been used on smaller fans before that time, the Dehue installation started a swing to idler drives which lasted until the short-center multiple V-belt drives began to make progress in 1927.



Contrasts in fan drives: From left to right, early double-reduction drive with flat belts, idlers with short-center flat belts, short-center V-belts

Inclosed gear reducer drives figured in several installations from about 1923 to 1927, but, while reliable, never were installed in numbers because of the expense of changing speed ratio and repair difficulties in case of failure—even though a remote possibility.

Electrical operation of fans in the early days of purchased power required an emergency power source at gaseous mines. Steam standbys were expensive if steam had to be kept up when not required for other purposes, and consequently the gasoline engine was adopted. Single-cylinder engines with clutch or belt-shifting connection were the rule up to 1920, in which year the Lincoln Gas Coal Co., Nanty-Glo, Pa., installed a high-speed marine-type engine directly connected to a 100-kva.

2,400-volt alternator supplying emergency power to the regular fan motor. Up to 1927, dozens of these emergency units were installed, with 300 hp. the most common size. Paralleling this installation of emergency units was a trend toward equipping fans with fully automatic controls. In 1927, a gasoline standby unit of the Lehigh & Wilkes-Barre Coal Co. was equipped with control equipment for automatic starting, power switching and stopping in case of line-power failure and subsequent resumption.

Although remote or semi-automatic controls were used as early as 1905, extensive application of automatic equipment to large fans did not begin until about 1926, following, in 1925, the installation of an automatic control with remote pushbutton change of rheostat position to effect speed control of the wound-rotor motor at the Nuttallburg (W. Va.) mine, Fordson Coal Co., by C. B. Locke, then electrical engineer. J. F. MacWilliams, electrical engineer, Pennsylvania Coal & Coke Corporation, Cresson, Pa., equipped five fans and ten substations with full-automatic controls in the same year.

First Locomotive D.C.

Modern electric locomotives are powered with series-wound d.c. motors, but here the similarity to the Lykens Valley unit of 1887 ends. The 32-hp. motor and chain-driven running gear of the first locomotive weighed 1,500 lb., cost $2,500 and was weighted to 7,000 lb. The d.c. voltage at times reached 400, and the conductor was an iron T-rail spiked to timbers. The Thomson-Houston locomotive installed by the Hillside Coal & Iron Co. in 1889 was equipped with a 40-hp. motor receiving current at 220 volts from a 1/0 hard-drawn copper trolley wire suspended from the roof through a wheel-type collector mounted on a reversible-type pantograph. Original weight was 10,500 lb., but 18,000 lb. of pig iron was later added to increase drawbar pull. The drive was through gears to a countershaft to crank rods on the wheels.

A single 20-hp. motor and double-reduction gearing to the axles featured the "George Upson," first bituminous locomotive, installed at the Shawnee (Ohio) mine, Upson Coal Mining Co., in 1888. Weight of the locomotive was 2 tons, and two 1-in. galvanized-iron pipes, one mounted about 10 in. above the other, and a four-wheeled trolley constituted Jeffrey's original collector system. Morgan-Gardner introduced the "third-and-traction-rail system" in 1899, followed by several other systems in later years, including, in 1906, the Jeffrey "combined rack-rail-and-friction-traction locomotive." Not until after 1920 did the last of the rack-rail systems go out of service.

About 1898 or 1899 (pp. 417–424) of this issue), a hand-cranked reel was mounted on a trolley locomotive of the Southwest Virginian Improvement Co., now the Pocahontas Fuel Co., to enable it to gather in rooms without wire. In 1900, probably the first mechanically driven reel was built in the shops of the Pocahontas Collieries Co., another Pocahontas Fuel company. Mechanical drives usually were employed until about 1916, when motor-driven geared reels —the forerunners of the ball-bearing directly connected motor-driven reels of today—began to increase in numbers. Crab-reel locomotives came into use about 1911, but their numbers began to drop after 1920 and only a few are used today.

In 1890, the largest locomotives in common use weighed 11 tons. In 1896, a 22-ton six-driver machine began a stretch of service extending to 1913, in which year several 15-ton units and a few of as much as 25 tons were employed. Subsequent design and size developments (see also pp. 417-424) were: 1915, Berwind-White Coal Mining Co., 30 tons (Jeffrey), six drivers, three 115-hp. 500-volt ball-bearing motors (first used by Jeffrey in 1910), 40-in. height, 15,500-lb. tractive effort at 8 m.p.h. and 33-in. rolled-steel wheels; 1918, H. C. Frick Coke Co., 30 tons, three 125-hp. 500-volt motors, Type M multiple-unit contactor control, straight air and hand brakes and 12,000-lb. tractive effort at 8.8 m.p.h.; 1922, Cambria Steel Co., 35 tons, 252 hp., three motors, electro-pneumatic control and air brakes with arrangements for dynamic braking; 1927, Berwind-White, 38 tons (Baldwin-Westinghouse, largest in the industry), six drivers, three motors, 390 hp. and Timken bearings on main journals and armatures. In 1935, a Baldwin-Westinghouse 15-ton locomotive built in a space 32 in. high, 72 in. wide and 15 ft. 3 in. long was installed by the Pocahontas Corporation, Virginia. Equipment included two 110-hp. motors, air brakes, air sanders and electro-pneumatic control.

Tandem locomotives (two 13-ton units) were being offered by one manufacturer before 1906, and in 1913 two 15-ton machines were being operated in tandem by the Carnegie Steel Co., Charleroi, Pa. Size has gradually increased to 40 tons in 1929 and 45 to 46 tons in 1936 (pp. 417-424). The 1929 units (two 20-ton machines in tandem) were equipped with anti-friction bearings throughout. Each 20-ton machine included two 150-hp. 250-volt motors geared for a speed of 11.5 m.p.h. at full load. Other features are solenoid-operated contactor-type controls with master drum controller, rolled-steel wheels and air brakes.

Slower speeds for gathering locomotives—a 1924 development—was an outgrowth of the use of combination battery-trolley units, which showed that the lower speed of these units on 125 volts in rooms, compared with 250 volts on the trolley, did not materially affect number of cars gathered in comparison with higher-speed cable-reel types. At the same time maintenance, demand and energy costs were less. Tests made at New Orient, Illinois, in 1926 (pp. 417–424) showed with approximately the same output a reduction of 38.4 per cent in energy consumption and 50 per cent less 5-minute demand in favor of the slow-speed type.

Locomotive Speed Cut

During 1926 and 1927 numerous cable-reel locomotives were changed to slow speed by rewinding or connecting the two motors permanently in series, and by 1928 all major manufacturers were offering units of 4 m.p.h. or less at rated drawbar pull. Now, the need for the greatest possible speed in changing cars after loading machines is causing a few companies again to favor high-speed types. Slow-speed conversion by connecting the motors in series had the disadvantage of a drop in pull in case one pair of wheels started to slip, which many companies met by a chain-and-sprocket connection between axles. Satisfactory results influenced some to add chains to units in which the series-parallel controls had been left unaltered. The chain eliminated the principal objection of motormen to starting in series.

Automatic switches for changing from trolley to cable reel were offered by the General Electric Co. prior to 1924, the unit consisting of a pair of standard contactors with mechanical interlock. In that year, C. B. Locke, electrical engineer, Fordson Coal Co., developed a simplified switch of the present type to meet the safety requirements of the Ford Motor Co. In a few years, switches for transfer duty were being built by several prominent electrical manufacturers. Thermostats in locomotive-field frames in conjunction with

sealed circuit breakers made their appearance in 1930, but as yet are used by only a few companies.

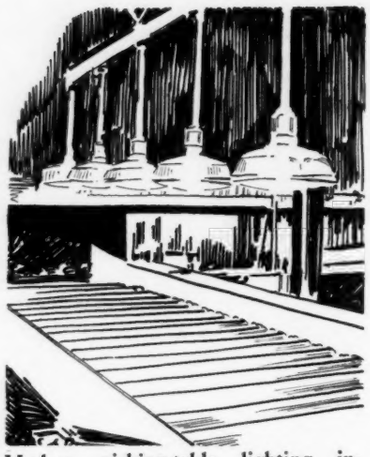
Gliders, the present standard collector device for heavy main haulage, go back to about 1925. In that year, the New Castle Coal Co., Alabama, replaced the trolley wheels on 10-ton locomotives with Miller shoes and found them far superior. Periodic wire greasing was found to add to the life of both wire and glider.

Although developed years before, storage-battery locomotives had made relatively little progress by 1911. Now, they gather and haul a substantial percentage of the output and provide the only U. S. Bureau of Mines "permissible" electrical traction. Predecessors of the Pocahontas Fuel Co. are credited with the early development and use of battery locomotives (pp. 417–424). Extensive use, however, apparently did not start until the years 1912-15. In 1913, for example, installations were made by the Grant Mining Co., Indiana, starting with 5-ton worm-gear locomotives and 63-cell nickel-iron-alkali batteries; Spruce Valley Coal Co., West Virginia, lead-acid cells; and the Philadelphia & Reading Coal & Iron Co., General Electric locomotive with nickel-iron-alkali 70-cell 300-amp.-hr. battery.

Battery Use Rises

By the middle of 1917, the Consolidation Coal Co. was using eighteen storage-battery locomotives in its West Virginia division and twenty combination units in its Kentucky divisions, all equipped with lead-acid batteries. Approximately 50 per cent of the locomotives sold in that year were battery equipped. The proportion declined in later years, however, the first nine months of 1925 showing 309 trolley and 105 battery units. In addition, a number of operations started up after shutdowns, particularly where grades were heavy, with battery locomotives converted to cable-reel types to save renewal battery cost. A few years later, however, battery types again began to gain because of their safety features and adaptability to tending loading machines.

Although an approach was made by one or two companies shortly before, the Bartley (W. Va.) No. 1 mine, Pond Creek Pocahontas Co., opened in 1924, became the first of the "wireless" type. The first battery-powered cutting machine went into service in this mine in December, 1924, and the first battery locomotive in January, 1925. Since that time, all cutting and transportation have been done by battery power, also



Modern picking-table lighting installation

adopted about the same time in the Carolina mine, Consolidation Coal Co., and the Coalwood and Caretta mines, Carter Coal Co.

In addition to mobile power units, storage batteries also have been applied to distribution systems for the purpose of supplying demand peaks, accumulating charge during periods of low demand. The floating battery originated in the early 20s in Illinois, where this system is now employed by the Sahara Coal Co. (September, 1936, *Coal Age,* p. 360). A floating battery also went in at the Big Four mine, McDowell County, West Virginia, in 1925.

First application of electric power to a cutting machine was an experiment by an agent of a local electric-light company at Streator, Ill., in 1885. In that same year, A. L. Sweet, general superintendent, Chicago, Wilmington & Vermilion Coal Co., who foresaw "the possibility of a generating plant at the center of the plant and all work done by electricity—even the mine lighted," promoted a chisel-shaped pick machine propelled by "a direct and reciprocating motion from an electric current" instead of the earlier rotary-motion motor.

In 1888, the electric motor had been developed to the point where it was a practical power substitute for compressed air, and in 1889, six 15-hp. Jeffrey electric cutters went into the Brush Fork No. 2 mine, Ellsworth-Morris Coal Co., Hocking County, Ohio. By 1899, over 1,000 of the 3,125 cutting machines in use were electrically driven.

Direct current has continued as the principal power for mining machines to the present day, largely, even though satisfactory a.c. machines were on the market in 1914, because of the preference for d.c. for locomotives and the doubtful economy of a supplementary low-voltage a.c. system. A.c. for mining machines was first tested in 1912 at the Rugby (Colo.) mine, Star Mining Co., using a Sullivan machine. Typical of induction motors, close voltage regulation is necessary. Of the many a.c. mining machines in service, most of them are used in small mines largely in small-tonnage States. One of the major exceptions is the Valier (Ill.) Coal Co. operation, with a capacity of over 1,000 tons per hour, where mining machines, drills and loading machines use a.c. All manufacturers use the squirrel-cage type of three-phase motor on a.c. machines.

Another factor which has slowed the use of a.c. underground has been the transformer fire and explosion hazard. To correct this drawback to transformer use, the General Electric Co. developed Pyranol, a non-inflammable, non-explosive cooling medium, first used commercially in 1933. Smaller transformer dimensions, another Pyranol characteristic, offer advantages where space is limited.

Although 550-volt d.c. still is used at a number of mines, the general preference at present is for 250 volts. Compound-wound motors of 35 to 50 hp. drive the cutter chains on mining machines.

As the development of mobile loaders came after the heydey of compressed air, electricity always has been the standard drive for this equipment, with 250- or 500-volt d.c. motors, principally of the compound-wound type, almost universally used until 1929, when a.c. motors began to gain ground, although only a few mines, as yet, are so equipped.

Few Steam Pumps Left

Electrification of pumping has proceeded to the point where but few steam units are left in operation. Both 1889 and 1890 are given as the date of the first motor-driven pump, but it was recorded in 1914 that the 1890 unit still was in operation. Soon after 1900, the a.c. motor began to displace the d.c. type—a process that still continues. Induction motors, principally of the squirrel-cage type, long standard for main pumping service, met their first synchronous-motor competition in 1908, when two 100-hp. drives were fitted to centrifugal breaker pumps by the Glen Alden Coal Co. From 1914 to 1926 that company installed fourteen additional synchronous motors ranging from 150 to 500 hp. on mine pumps, presaging a rapid increase in use after 1930.

Maximum sizes of pump motors

now in use are: synchronous, 800 hp.; squirrel-cage induction, 1,000 hp. Centrifugal pumps in the Jermyn station of the Hudson Coal Co., completed in 1925 and the largest in use today, have an aggregate capacity of 33,000 g.p.m. against a 270-ft. head. The pumps are driven by four 500-hp. and four 300-hp. squirrel-cage motors.

Although limited automatic control, mostly stopping with a float switch, goes back to the early days of pumping, the first completely automatic station was not installed until June, 1923. This station, at the Draper colliery, Philadelphia & Reading Coal & Iron Co., was the product of a suggestion by J. T. Jennings, electrical engineer. Collaborators in the design were B. M. Horter, Cutler-Hammer; Guy V. Woody, Allis-Chalmers; and Otto Haentjens, Barrett, Haentjens & Co. The resultant control provided for automatic priming by vacuum pumps and protection against practically every type of mechanical and electrical failure.

150 Automatics in 1927

By 1927, according to a survey reported by Mr. Jennings, approximately 150 automatic pumping plants were in operation in anthracite mines. Improvements since the 1923 installation have revolved largely around electrical simplification, furthered by the Hazleton suction-line primer in 1931, which has displaced vacuum pumps in many small and moderate-sized stations, as well as a few large ones.

Automatic starting of d.c. gathering pumps, principally of the reciprocating type, after a voltage failure was early recognized as an urgent necessity, but proved a most difficult problem. Many automatic starters were tried prior to 1920, but few were satisfactory. Poor voltage regulation was the principal trouble. Starters especially designed for mine service, such as, for example, the Ohio Brass KD and KSD, together with the better voltage regulation, have at present largely surmounted this long-standing difficulty in gathering-pump control.

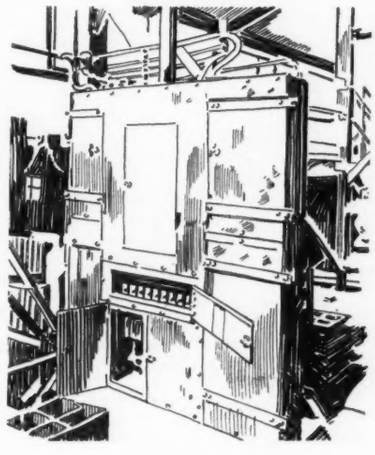
Permissible equipment is entirely a development of the last 25 years. Five manufacturers, at the behest of the U. S. Bureau of Mines, submitted motors for test as "explosion-proof" in 1912, and by 1914 development had proceeded to the point where Bureau requirements were met. On Oct. 20, 1914, Permissible Plates 100 and 100A were granted the Sullivan Machinery Co. on its CE-7 shortwall cutters.

Early work, dating back to 1903, was based on building an electrical motor with an inclosure that would prevent the flame of an arc inside the motor from igniting material or explosive gas surrounding the motor or, on the contrary, prevent explosive gas from entering the motor. Not until after the Bureau of Mines was organized was the really safe specification adopted: i.e., an inclosure that would prevent the flame from the ignition of an explosive mixture inside the motor from igniting an explosive mixture surrounding it.

Forty permissible plates were issued in the first ten years of granting approvals, covering compressors, loading machines, coal drills, mining and shearing machines, room hoists, mine pumps, gathering and main-line locomotives and battery power trucks. Now, practically every type of electrically powered underground equipment is available in permissible construction. And in 1934, approved cutters in use numbered 5,218 out of a total of 11,905.

Use of electric motors to retard and govern overhauling loads lagged until 1920 and did not become common until 1928, largely because of the early prevalence of d.c. motors which are not inherently adapted to regeneration, as are induction motors, without special auxiliary control apparatus. Adaptation of the motor to governing speed and braking the load when lowering empties dates from practically the time of the earliest a.c. motor application to slope hoists in the pitching seams in the anthracite region and the Western States. By 1927, a survey showed, the practice had become general in the West, but was little used at bituminous mines in the Central and Eastern States. At that time,

Factory-assembled dust-tight control cabinets are latest practice in preparation plants



the United States Fuel Co. had applied at the King No. 1 mine, Hiawatha, Utah, a 500-hp. wound-rotor motor to brake an incline machine lowering trips of seventeen loads down a mountainside incline 5,800 ft. long with an average grade of 12 per cent. Brake-block wear was practically eliminated, 1 kw.-hr. per ton was fed back into the line and rope life was doubled by smoother braking.

Since that time, a number of incline machines braked by regeneration have been installed in the East, of which the first was a 500-hp. unit at the Closplint (Ky.) mine, Clover Splint Coal Co. Governing the speed of an overhauling rope-and-button conveyor, an ideal application for the induction motor, was seldom practiced before about 1928, many conveyors from 1916 to that time being equipped with automatic mechanical brakes.

Dynamic Braking Limited

Dynamic braking of hoists by exciting the stator of the induction motor with d.c. has been applied but few times in coal mining. In 1916, a 700-hp. motor at Packer No. 2 slope, Lehigh Valley Coal Co., was thus adapted by adding an 18-kw. m.g. set and the necessary controls. The Consolidation Coal Co. applied the same scheme to a hoist motor handling slate at the No. 93 mine, Jordan, W. Va., in 1934. Lower power consumption, better control and lower maintenance are the advantages over plugging. Only a few mine locomotives have been fitted for dynamic braking because few operations have grades of sufficient length and steepness to justify the additional control apparatus. The 35-ton locomotives of the Cambria Steel Co., Rosedale, Pa., were so equipped in 1922, however.

Other electrical applications around coal mines include signaling and switchthrowing (pp. 417–424), light-sensitive tubes to control mine-door operation automatically, sound warning signals and control washer slate-gate operations; vacuum tubes, in public address systems incorporated in safety programs; mine telephones and illumination.

The telephone, adopted extensively elsewhere by 1884, probably was tried in mines before 1900, followed by installations of one or two underground at numerous mines up to 1912, in which year an ironclad instrument was developed to cure the moisture problem, which, with poor insulation and protection of lines, militated against satisfactory results. After that time, use gradu-

ally increased until about 1925, when a sharp upward move occurred with the growing trend toward dispatching and mechanization. A permissible unit was offered in 1927, coinciding with the start of the practice of placing lines in ducts buried in the mine floor.

Although line-powered lamps are used on haulways and in certain other underground openings in coal mines, light for the individual workman is based primarily on cap lamps, as very few hand lamps are used for illumination in the United States. The electric cap lamp (pp. 417-424 of this issue) made its appearance about 25 years ago. Improvements in lamp bulbs and batteries have increased light quantity from 18 to 40 lumens at the end of the sixth hour. Modern lamps provide an average illumination of slightly over 7 foot-candles at 3 ft.

Electric lights in surface plants date from the Hillside Coal & Iron installation of 1887. However, it was not until 1930 that picking-table lighting of the standard type came into use. Prior to that time, lighting generally was highly inefficient because of lack of capacity, dirty lamps, lack of proper reflectors, glare or improper position. Research and practical experiments by the Westinghouse Lamp Co., culminating in the model installation at the Johnstown (Pa.) mine, Imperial Cardiff Coal Co., in 1930, was followed by numerous picking-table installations. Usually, 300-watt Mazda incandescent lamp units are mounted 30 in. above the table on 2-ft. centers, providing an average illumination of approximately 50 foot-candles. The lamps are installed in porcelain-enameled reflector units with dust-tight cover glasses. The latter may be day-blue or daylight lamps may be used.

On the other hand, many companies have used low-intensity mercury-vapor lamps because experiments have indicated that pyrites and certain other impurities show up better. Following trial of the new high-intensity lamps in 1934, a number of these 400-watt mercury-vapor units were installed over picking tables in 1936, including, in southern West Virginia, American Coal Co. of Allegany County, Boone County Coal Corporation, and the Chafin-Jones-Heatherman Coal Co. With these high-efficiency (40 lumens per watt) lamps 30 in. above the table on 4-ft. centers, illumination averages 200 foot-candles and yet there is no noticeable glare.

From the wiring and control standpoints, recollection of the open wiring, unprotected manual-starting rheostats and link fuses general in 1911 emphasizes the progress evidenced in 1936 with complete preparation plants equipped with overload breakers instead of fuses, contactor-type motor controls mounted in dust-tight factory-assembled central cabinets and circuits inclosed in BX armored cable. Although some rigid conduit was used in 1911 to protect electrical wiring, high cost, vibration in tipples and breakers, occasional collection of moisture at low points and failure to ream ends, with consequent grounding, restricted its growth, so that up to the time BX cable began to come in, conduit had not entirely replaced open work. Now, as a rule, rigid conduit is used only for heavy circuits.

Except in anthracite breakers, the general practice up to 1924 was to mount starters near their respective motors to reduce wiring cost. About that time, the high-torque double-deck squirrel-cage motor became available to replace the wound-rotor type, resulting in an increasing disposition to use automatic starters on motors even if remote control was not required. These factors resulted in grouping starters at a point in the tipple free from dust and moisture and convenient for inspection and maintenance. A tipple at Weeksbury, Ky., rebuilt by the Elkhorn Piney Coal Mining Co. in 1925, was equipped with General Electric double-deck squirrel-cage motors started by magnetic switches grouped at one point.

Control apparatus has undergone marked simplification through the development of linestart motors which eliminate the compensator or resistance previously used to reduce starting voltage. Two 1,000-hp. linestart squirrel-cage motors were installed in an anthracite pump station in 1934. The Lehigh Navigation Coal Co. operates a full-automatic compressor driven by a 650-hp. linestart synchronous motor at Nesquehoning, Pa., and a 600-hp. synchronous fan motor of the Pond Creek Pocahontas Co. also is of the linestart type. Another development which had simplified control is the use of Madden slip-ring starters and plain squirrel-cage instead of wound-rotor motors. These automatic clutch-type starters were installed by Lehigh Navigation in rebuilding the Tamaqua breaker in 1935.

COAL INDUSTRY LOOKS TO RESEARCH

By CLYDE E. WILLIAMS
Director, Battelle Memorial Institute
Columbus, Ohio

DURING the last quarter of a century we have seen the coal industry rise to a peak of production and then start to decline. The peak of the output was in 1918; the net income of all coal mining corporations, both bituminous and anthracite, was highest in 1920. Since that time the industry as a whole has shown a profit in only three years (Table I). The substitution of other fuels for coal has been a serious blow to the industry. With excess capacity already available, the loss of markets and increased labor costs have presented a difficult problem.

Numerous plans have been proposed and some tried to lift the industry from the grips of its depression. But most of such plans have run counter to the law of supply and demand and so have not succeeded. The earning position of the coal industry could be improved by: (1) lowering the costs of production, selling and distribution; (2) increasing sales, and (3) raising the price of coal. Much progress already has been made in the mechanization of mining and in the development of cheap and efficient methods of preparation, and continued improvement may be expected. Simplification of the marketing of coal, particularly to the domestic

Table I—Earnings of All Coal Mining Corporations in the United States (Bituminous and Anthracite)[1]

(In Thousands of Dollars)

Year	Total Number Active Companies	Reporting Profit, Per Cent	Gross Income	Income Taxes	Net Income After Tax	Per Cent Net to Gross
1916	2,698	68.1	$760,229	$2,399	$99,962	13.1
1917	*	*	*	*	*	*
1918	3,129	69.0	1,828,290†	76,961	94,315	5.2
1919	3,228	48.9	1,525,543†	17,701	57,692	3.8
1920	3,673	81.0	2,564,185†	107,048	238,925	9.3
1921	3,656	29.5	1,652,289†	15,219	D-5,086	D-0.3
1922	4,110	60.0	1,548,520†	15,633	94,976	6.1
1923	3,872	35.9	2,021,408†	15,430	61,927	3.1
1924	3,516	23.6	1,539,857†	5,554	D-53,419	D-3.5
1925	3,767	29.2	1,133,483	5,587	D-27,995	D-2.5
1926	3,679	36.7	1,633,624	10,647	27,067	1.7
1927	3,131	34.7	1,417,319	7,765	D-28,067	D-2.0
1928	2,831	32.4	1,299,916	5,120	D-24,377	D-1.9
1929	2,580	37.5	1,308,243	5,280	D-14,160	D-1.1
1930	2,348	34.9	1,190,261	3,907	D-37,869	D-3.2
1931	2,187	28.1	971,734	1,661	D-51,020	D-5.3
1932	1,971	16.3	735,895	983	D-68,847	D-9.3
1933	1,986	22.1	781,908	1,472	D-59,878	D-7.7
Total, 1916-33	3,080‡	40.5	$23,912,704	$298,367	$304,146	1.3
Total, 1921-33	3,049‡	32.4	$17,234,457	$94,258	D-186,748	D-1.1

* Not reported. D–Deficit. † Total value of coal produced, as reported by the Interior Department, Bureau of Mines, is used in place of gross corporate income, which was not given in the Treasury Department statistics of income for these years. ‡ Average number.

[1] "Economic Conditions," National City Bank of New York, June, 1936.

trade, offers much promise of reducing the spread between costs at the mine and at the point of consumption.

Increased sales can be obtained by finding new uses and by improving the utility of coal in relation to other fuels in present uses. For the industrial and railroad consumers the primary requirements in fuel are low cost per unit of heat and high efficiency. For the domestic consumer the primary requirements are convenience, cleanliness and, last of all in point of importance, low cost. For the steamship companies the primary requirements are a concentrated fuel that can be stored in a small space, high efficiency, and low cost. For the coke manufacturer the requirements are good coking properties, low ash and sulphur content, uniformity, and low cost.

While greatly increased production is needed, because of the excess of active capacity of the industry, it is also essential that a higher price per ton be recovered. As is shown in Table I, the industry as a whole lost money in some of the years when total production was highest. If the consumer is to pay a higher price for coal, he naturally must receive greater value from it. For example, the large industrial user must obtain a lower cost per unit than from competitive fuels before he will pay a premium over present prices; the householder must receive greater convenience and cleanliness before he will pay an increased price. A higher price for coal requires an actual increase in value from some standpoint. As in the case of increased sales, a higher realization involves primarily technical improvement either in the coal itself or in the means of utilizing it.

These problems and objectives are not confined to the coal industry. Other large, basic industries have them and many have mastered them through research. The petroleum industry offers an excellent example. We are prone to look upon the coal industry as old and the oil industry as relatively young. Yet it is reported that the Persians burned oil two thousand years ago and yet many of us can remember when gasoline was considered a wasteful byproduct in the production of coal oil. Research in the development of the automobile and the simultaneous research by the oil companies in the development of better gasoline and lubricants have been responsible in large part for the phenomenal growth of these two industries.

However, we can also find excellent examples within the coal industry itself. One of these is the simplification in marketing and distribution effected by one large organization. Another is the progress made by machinery manufacturers in mechanical mining, both underground and on the surface. Still another is the progress made in developing and improving the methods of cleaning coal.

As in the mining and preparation of coal, much good has been accomplished by research work in the utilization of coal. Development in both the industrial stoker and pulverized coal-burning technique and equipment since the World War has been revolutionary. Another instance is the research done in carbonization. In the case of low-temperature carbonization the development has not been commercially successful thus far. This has been due to various causes, one of which is a failure to find a profitable outlet for low-temperature tar. This

• Since industrial executives in this country are now looking to technical research to solve the problem of extending the uses of their products, it is safe to predict that the coal industry too will increase its activities in that direction. In the past, this work has been held back by the fact that no single bituminous company or small group of companies represented a large enough part of the industry that it felt warranted in doing research and development work on which its competitors could capitalize. Organization of Bituminous Coal Research, Inc., however, has changed the picture.

• Thus, although the stronger coal companies will continue their individual research work, the industry as a whole will cooperate in carrying out the broad program essential to its economic improvement. Bituminous Coal Research, Inc., supported by the National Coal Association and many individual companies and groups of companies, has now successfully completed its first year's activities. In the coming years, the results of the research work of this organization and the stimulation that this joint effort will give to the individual coal companies, equipment manufacturers and other research agencies will be an important factor in improving the position of this great natural resource.

• Now that the industry is cognizant of its problems and is prepared to carry on research work with a view to solving them, it is the belief of the author that the industry may safely consider that it is now entering a period of greater promise than at any time since 1920.

is one example where research to date has not paid returns. On the other hand, research in high-temperature carbonization has resulted in cheaper and better coke with a consequent expansion of the steel industry and of associated industries using the byproducts of coke manufacture. At the same time it has resulted in the marketing on a large scale of byproduct coke for domestic use.

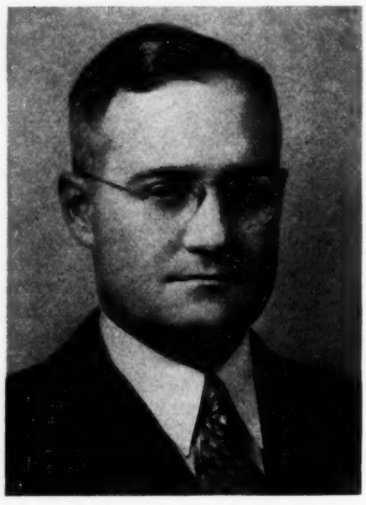
Many other cases could be enumerated wherein research has resulted in increased efficiency in power and heating plants and in the increased value of coal in comparison with competitive fuels. In fact, it is because of research done on coal that it has succeeded in maintaining its position as well as it has. Although these various improvements effected by research have resulted in a smaller consumption of coal per unit of power developed, and therefore have represented an apparent loss of coal tonnage, they have served to maintain coal's position as a fuel and have prevented larger replacements by competitive fuels that otherwise would have taken place. So, too, the development of the small stoker, by giving the domestic consumer the convenience he demands, has done much to hold domestic business for the coal industry and to recapture business that had gone to competitive fuels.

Interest in Research Spreads

Coal research in the past has been done largely by individual coal companies, users of coal or manufacturers of equipment involved in the use or handling of coal, universities and government experiment stations. In recent years individual coal companies and equipment manufacturers as well as some universities have greatly increased their research effort. In addition, such agencies as the National Coal Association, Bituminous Coal Research, Inc., and Appalachian Coals, Inc., have undertaken active work either in marketing or technical research.

Market research is being directed toward the development of more economical methods of selling and distribution so that coal may reach the ultimate consumer in the most direct manner possible; the development of methods for taking care of seasonal variations in market requirements; and study of special requirements of coal for certain industries. However, it has been realized that the most important marketing problem—the increase of sales and of sales realization—depends upon technical developments to improve the competitive position of coal in relation to other fuels and so the main effort at the present time is being directed along technical lines. Developing cheaper mining methods and cheaper and more efficient coal preparation methods is being taken care of today by equipment manufacturers in a highly satisfactory manner, and so there has been no need for the coal industry to enter this field.

An important part of the technical program now under way is devoted to stokers for the domestic user and for the small industrial heating plant. This work involves the determination of the quality of coal required for best operation of standard equipment now on the market. It also involves the development of equipment that will burn other coals and sizes of coal that cannot now be handled successfully. The whole effort is directed toward providing equipment that will burn a great variety of coals with cleanliness and convenience. This problem of improved stokers for domestic and small heating plants is of immediate concern to the coal industry and is rightly being given primary attention.



CLYDE E. WILLIAMS

Since his graduation from the University of Utah, Mr. Williams has had a wide experience in the mining and metallurgical industries. After several years in the West, particularly with the United States Smelting, Refining & Mining Co., he joined the staff of the U.S. Bureau of Mines and later became superintendent of its Northwest Experiment Station at Seattle. There he had charge of the Bureau's work on coal and iron and steel investigations. In 1924 he assisted H. Foster Bain in an investigation of the feasibility of the development of iron, steel and coal industries in the Argentine. Subsequently, he was with the Columbia Steel Corporation. Late in 1929 he was offered the post of associate director of Battelle Memorial Institute, which maintains a large research laboratory in Columbus, Ohio, devoted to the advancement of the fuel, metallurgical, ceramic and chemical industries. Mr. Williams was made director of Battelle in 1934.

Paralleling this work on the part of the coal industry, the stoker manufacturing industry is making great strides in improving its equipment and manufacturing and marketing methods. The time probably is not far distant when the small stoker, once manufactured expensively on a small scale, will be made by large-scale production methods and will be available at low prices, following the history of the automobile and the mechanical refrigerator.

Further Study Needful

Other work on which research is being directed, but which requires much greater effort, has to do with large commercial heating units, and industrial stokers and pulverized-coal installations. Work is needed on the relation of the characteristics of various coals to their performance on large underfeed stokers. Similar work should be done on pulverized coals to determine their burning characteristics in pulverized form and the relationship of these characteristics to other properties of the coals.

Extension of the use of oil-burning locomotives and of the diesel engine in railroading demands that immediate attention be given to the problem of improving coal-burning locomotives. Work should be done to improve the design of the combustion chambers for both hand- and stoker-fired locomotives to reduce losses of fuel in the stack and in the ash, and to obtain more efficient combustion. In addition, work should be done on the development of a locomotive for pulverized coal.

The recent successful operation of a locomotive driven electrically by fuel-fired steam turbines should be followed up, as it gives promise that coal may be used advantageously in place of oil in the diesel engine. These are all problems in the railroad field that merit the immediate attention of the coal industry. In numerous other industrial operations, such as in the heating of metals and ceramic materials, where coal has been replaced by oil or gas, there is

opportunity for study with a view to improving combustion of coal, all of which would play an important rôle in recovering lost markets.

Finally, no program of technical research would be complete without some consideration of possible new uses for coal. Although this is always a hazardous subject and one that is more or less speculative, it is necessary that attention be given to certain proposals which, if successful, would lead to a greater consumption of coal.

One suggested use for coal is as a raw material for the production of chemicals. Although this will not provide a large outlet for coal, we have seen many small products of the chemical industry grow in a few years to large proportions, and so this problem should be included in any broad program of work.

Another use for coal that might be greatly extended is as a gaseous fuel. Since the cost of transportation represents so large a part of the final cost of coal to the users, many engineers have advocated complete gasification at the mines. This involves a cheap method of producing gas of high calorific value. The gas producer offers the cheap method, but some way must be found to produce a gas of higher calorific value than is now possible. One solution is to operate the producer with oxygen-enriched air. This in turn creates a research problem in that it involves the development of a cheap method of producing oxygen. In any event, complete gasification is a problem that merits consideration for the future.

A third use is as a fuel for automobiles. The fuel requirements of the automotive industry are so great that the coal man looks upon this market with covetous eyes. He is told that when oil becomes high-priced, coal will be liquefied and a suitable product abstracted for use in internal-combustion engines. Immediately, he sees the prospect of putting all coal into a liquid form, with the consequent solution of most of the knotty problems facing the coal industry. Although this Utopia is many years distant and becomes further distant with each large discovery of oil, nevertheless the liquefaction of coal is a worthwhile problem for research. It is now being studied in a small way by several agencies in this country and is receiving important attention abroad where petroleum is less plentiful. The problem merits further attention as a safeguard for the future.

Still other suggestions for the use of coal in the automotive industry have been seriously considered by engineers: namely, in internal-combustion engines in a pulverized form and also in turbine-driven, fuel-fired steam engines.

A fourth use is as an oil-coal emulsion (colloidal fuel). Advocates of this use of coal bob up from time to time. It has been advocated especially for ships. Work should be done to settle the question as to the commercial practicability of using this type of fuel.

In conjunction with this applied or engineering research, work on fundamentals is highly important. The advancement of old or the development of new uses for coal depends upon the utilization by the research engineer of fundamental physical and chemical facts relating to coal. Our universities, governmental bureaus, and research institutions should be encouraged to increase their activities in this field. The fine work under way at the coal research laboratory of Carnegie Institute of Technology on the fundamentals of combustion, hydrogenation and carbonization, and that of the U. S. Bureau of Mines on combustion and carbonization are examples of this form of research.

MAINTENANCE

CONSIDERING the relative degree of electrification and mechanization, maintenance cost 25 years ago was fully ten times the present figure, not to mention the other handicaps growing out of more delays and increased power waste. Changed attitude on the part of the management, adoption of gas and arc welding, use of anti-friction bearings, employment of pressure and centralized lubrication, closer d.c. voltage regulation and better materials are the major factors in the improvement in the past quarter of a century.

Today, low maintenance costs for bituminous mines with favorable conditions may be expressed in steps of five: i.e., 5c. per ton total without mechanical loading or cleaning, with 5c. additional to maintain loading machines and a further 5c. to maintain mechanical-cleaning equipment. Lubrication costs are included in these approximate figures, which may be lower for certain types of loaders and cleaning plants, while the base figure may be two or three times 5c. where unfavorable conditions of depth, pitch, gas and water prevail. As a rule, conditions at anthracite mines make the total maintenance cost three to five times that of favorably situated bituminous mines.

With a few companies, excellent maintenance management has long been the rule, but with the majority it dates back only to the general use of mechanical loading, which drew attention to the fact that maintenance is an operating problem. The general attitude in 1911 was that machine failures were to be expected and that the principal effort should be expended on making repairs rather than on research into the reason, supplemented by steps to prevent a repetition—the common practice of today.

Prominent among the larger companies with a management that saw maintenance in its true light before the advent of large-scale mechanization was the Island Creek Coal Co., of West Virginia. Mechanics and electricians inspecting and repairing underground machinery in all mines reported directly to the superintendent of d.c. equipment, who recorded every failure every day, determined the cause, if possible, and took steps to prevent a repetition. The company also took the position that recurring failures due to defective design of machinery parts should be eliminated by replacement with improved parts. Standardization was still another principle early incorporated in the Island Creek program.

Under favorable conditions, production delays caused by equipment failure total less than 1 per cent of the working time at fully mechanized mines. Maintenance of modern loading machines at a point where delays are less than 2 per cent and locomotives at a point where delays are less than one-tenth of the loading-machine figure is not uncommon at the present time.

It is possible that a few companies were making limited use of Thermit and gas-welding processes in 1911, but it is certain that in 1915 the Kellys Creek Colliery Co.,

Ward, W. Va., was employing Thermit to repair broken steam-locomotive frames. Following the stimulation of interest growing out of publicity on its successful use in building Liberty engines late in the World War period, the coal industry began to apply arc welding to repair work in 1919.

Arc welding was used to fill worn locomotive tires in 1923 at two Kentucky shops of the Consolidation Coal Co., Jenkins, and the Elkhorn Piney Coal Mining Co., Weeksbury. One company was using worn machine bits as fillers in tire welding in 1927 and early in 1928 the Davis Coal & Coke Co., Thomas, W. Va., was using ½x1½-in. high-carbon bar steel for the same purpose. In 1936, manual arc welding of tires is a common, but not universal, practice and the filler-band method is well established.

Filling tires with an automatic arc-welding machine was tried at Jenkins, Ky., in 1921, and was made a regular practice at the Indiana (Pa.) central shop, Clearfield Bituminous Coal Corporation, in March, 1930. One automatic arc welder at the Scranton (Pa.) shop, Westinghouse Electric & Mfg. Co., is kept busy on tires from near-by anthracite companies and street railroads.

In addition to the general work of joining parts and filling or building up worn surfaces, gas and arc welding have played a major rôle in coating or plating wearing surfaces with tungsten-carbide or other extremely hard materials as a means of reducing maintenance. Mining-machine clutch faces are an example of increased life from plating. Plating or coating cutter bits—almost new in 1930 but now approaching common practice—has proved a tremendous advantage from the standpoint of increased machine production, reduced power consumption and decreased maintenance cost of bits and machine parts. Expert welders using a gas torch can tip as many as 7,000 bits per pound of hard-surfacing materials. In some types of cutting, plated bits will turn out ten times the tonnage of untreated types.

Introduction of bit-sharpening machines was a major step in bit treatment antedating hard-surfacing by ten years (the roller sharpener now in general use was first offered by Sullivan in 1921). The magazine heater, in common use today, appeared a little later. Heat-treating of bits and the use of special types and special steels or alloys are other practices which have made substantial progress since 1930.

Anti-friction bearings, which have revolutionized bearing maintenance and lubrication and markedly extended the performance life of certain types of motor armatures, were just coming over the horizon 25 years ago. A few mine-locomotive motors were fitted with ball-bearing armatures in 1911, and one of these, an SKF, gave seventeen years of continuous service on a 5-ton Jeffrey locomotive, North-East Coal Co., Paintsville, Ky.

Although the maintenance advantages of ball bearings on locomotive armatures were well recognized by 1916, the World War boom and the two subsequent years did not encourage extensive rebuilding of old locomotives to accommodate this equipment. In 1924, however, the movement took on proportions, and gained strength in the next few years so that today a locomotive with plain-bearing armatures is the exception.

Roller-bearing mine-car wheels (see also pp. 417-423) were offered in the early 1900s, and from 1908 to 1920 both the spiral and straight-roller types were widely used. By 1924, the Timken tapered roller bearing, introduced on mine cars in 1920, had proved its advantages at a number of mines as a preliminary to a widespread usage. Ball bearings were tried in car wheels 15 or 20 years ago, but their use did not begin to gain until 1933. Since that time, approximately 85 per cent of the cars of the Sanford-Day company, which developed the ball-bearing "Floater" wheel in 1933, have been so equipped. Now, the majority of the cars used by the coal industry are running on anti-friction bearings of one type or another.

Anti-friction bearings also have been standard for belt-conveyor idlers for over ten years. And in that period, their use has been extended gradually from the driving motors to the other bearings of mining and loading machines, preparation plant machinery and numerous other equipment types.

The change in lubrication methods from the "blackstrap pouring" of 1911 to the centralized automatic system of 1936, which unfailingly and sparingly feeds out the highest grade of lubricant, was hastened by the rise of the anti-friction bearing—characterized by small clearances, high renewal cost, large surface exposed to the entrance of dirt and inherent lubrication requirements demanding tight inclosures and, consequently, pressure-gun lubricant application.

Motor crew waits while the "iron mule" is fixed—a much less common occurrence under present maintenance standards

Lubrication Centralized

Centralized lubricating systems for preparation plants and mobile equipment, such as locomotives, were being offered by the Keystone Lubricating Co. in 1923. By the turn of a handwheel on a stationary cylinder previously charged with the lubricant, the latter was forced through pipes and rubber tubing to a group of bearings—perhaps as many as 25, with some of them moving. The locomotive lubricator consisted of a grease manifold with tubes connecting it with the bearings. By 1927, the Pittsburgh Coal Co. had equipped its mining machines with extended grease tubes permitting grouping of intake fittings at one place on each machine to make hand-gun lubrication certain and conveni-

ent. This method was offered by the Hulburt Oil & Grease Co. in 1928. In the same year, the Lincoln Steel & Forge Co. was finding a ready sale for its mine-car lubrication system of 80-lb. tank with pneumatic pump and automatic grease plugs.

Lubrication of apron or pan conveyors was changed from the inefficient and costly manual method to a precise and automatic method in 1928 by an invention by W. A. Hunt, then general superintendent, Island Creek Coal Co., which had installed 40 of these lubricators by 1927. Pistons operated by a roller contacting each wheel squirted a few drops of oil on the bearing at each side as it passed. The Hunt oiler later was marketed by Hulburt.

A further improvement in preparation-plant lubrication—the motor-driven pump and centralized system of the Ideal Lubricator Co.—had come into use by 1928. Now, many of the large anthracite and bituminous plants are so equipped. At three breakers of the Lehigh Navigation Coal Co. fitted with this system, labor and material cost of lubrication had been cut from 1.47c. to 0.58c. per ton in 1935.

A little over two years ago the Alemite Model 6110 electric mine-car gun was offered for direct attachment to the shipping drum to prevent contamination and save the time otherwise involved in transferring the lubricant and in releasing and building up pressure in the pneumatic machine. One of the first installations, at the Coalgood (Ky.) mine, Mary Helen Coal Corporation, paid for itself in twelve months, according to S. J. Dickenson, general manager. Accurate gaging of the grease injected into each bearing is made possible by flow meters. Other users include: Stonega Coke & Coal Co., Pocahontas Fuel Co., Consolidation Coal Co., Jamison Coal Co., Industrial Collieries Co., Carbon Fuel Co. and Wyatt Coal Co.

Portable Greasers Used

An outstanding development in loading-machine maintenance was the introduction of a portable greasing station (storage tanks and motor-driven applicator mounted on a mine truck), which took root in 1930 and now is used at many of the larger mechanized mines. This and the many lubrication improvements of the last 25 years all have been important factors in reducing maintenance cost.

Improved materials which increase strength, reduce corrosion or decrease weight of parts, plus improved electrical insulations, have cut slices off the maintenance cost. Some of these were adopted promptly but others lagged for years awaiting general acceptance of the fact that extra money invested in superior equipment is well spent. Again, it took mechanization and time-study revelations to turn the trick!

Alloy and special steels go back to about 1890. Except for a few minor items, special heat-treated steel was first used for mine-locomotive replacement gears. In July, 1909, the Berwind-White Coal Mining Co., Windber, Pa., placed an order for 36 pinions with the Tool Steel Gear & Pinion Co. By 1916, this organization and the R. D. Nuttall Corporation had placed a number of special gears at coal mines, but not for ten years did locomotive manufacturers generally begin regularly to equip new machines with comparatively long-lived gears.

Foreshadowing by more than fifteen years the present trend in loading-machine construction, the Hunt loader tried at the Weeksbury (Ky.) mine, Elkhorn Piney Coal Mining Co., in 1921, was equipped with Timken bearings throughout, heat-treated chrome-vanadium gears and steel castings. No failures in exceptionally hard digging in poorly broken-down coal proved the merits of the design.

★ ★

QUALITY RISES

● The automotive industry, through research, has developed materials which make possible the light, cheap, durable car that we have today. Much of its research has been on the metallurgy of iron and steel. The materials that have been developed by that industry have been gradually introduced into the coal industry.

● The majority of manufacturers of mining equipment are today building machines that stand up to service instead of turning out equipment that gave them a very lucrative business in repair parts. In general, the equipment of today is built of materials that have been selected because of their particular fitness for the job. I refer particularly to alloy steels in place of ordinary cold-rolled steels, roller and ball bearings in place of plain bearings, cast steel in place of cast iron, non-corrosive steels in place of ordinary steels, etc.

● The oxyacetylene torch and electric welder make possible the maintaining of a greatly increased amount of equipment quickly and at a low cost.—Paul Weir, vice-president, Bell & Zoller Coal & Mining Co., Chicago.

Bit-tipping, a modern adaptation of the gas-welding process which made its start about 1911

The light, tough 90- to 95-per-cent aluminum alloys already were attracting attention 25 years ago, and now are applied in a number of mining services, of which a major one is stripping dippers, dragline booms, etc., where lighter weight permits handling greater quantities or the use of longer booms. Alloys of chromium and steel did not attract wide attention as substitutes for bronze in mine pumps handling acid water until 1920. Tests showed their superiority, but higher manufacturing cost, as compared with bronze, has allowed the latter to hold its position as the principal material for large centrifugal pumps. The anti-acid bronze is an alloy of copper and tin with small percentages of other elements such as, for example, manganese and phosphorus. Generally speaking, the chromium alloys are used in the smaller anti-acid pumps where material cost is a less significant item.

Special Steels Progress

Although plain carbon steel has been the favored metal for screens, chutes, etc., in preparation plants, special steels and alloys have attracted increased attention in the years since about 1920 or 1925, although certain types, such as manganese bronze, were used still earlier in notable quantities. In 1927, it was estimated that about one-fifth of the annual consumption of screen metals in the anthracite industry was manganese-bronze and other corrosion- and wear-resisting metals. Since that time, the proportion probably has increased, and a substantial vol-

ume of special metals has gone into the construction of chutes and other plant equipment subject to corrosion and wear as well.

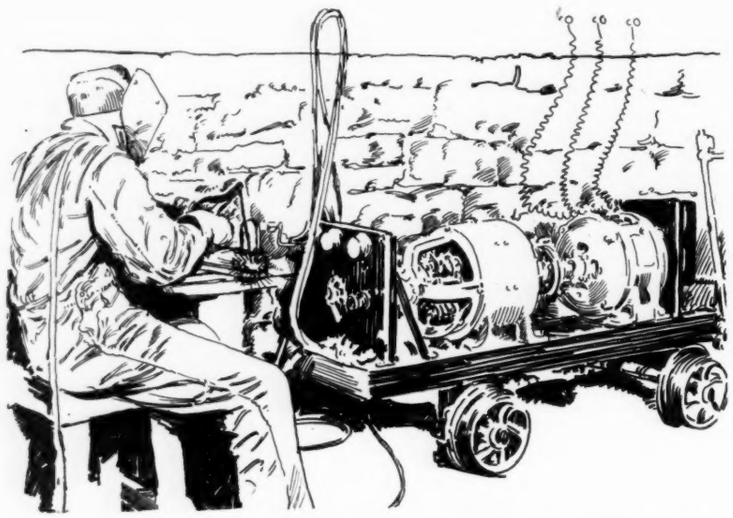
Special steels of the high-strength type, in some cases also offering a degree of resistance to corrosion, have made progress in the last two or three years in coal-truck bodies, mine cars, stripping dippers and other services where decreased weight is a factor.

Cost of wire-rope renewals has been reduced to about one-fourth the figure of 25 years ago. Factors in this decrease include: better and more uniform steels, new constructions, such as preforming, which first made its appearance at the mines in 1924; improved lubrication practices, and research by coal companies into the causes of short rope life supplemented by corrective measures. Life, consequently, has been extended to many times the early figures.

ing at the central shop at definite intervals dependent on the type of equipment and at irregular intervals where needed are now customary, leaving only minor repairs and replacement to the trouble-shooting mechanics underground.

Complete units of a machine now are included in the replacements instead of intricate items of the unit. An early example of this trend was the assembly of the locomotive armature with its ball bearings and housings in the central shop instead of renewing only a ball bearing or an armature. A more recent example is the replacement of complete loading-machine heads, instead of only a single worn or broken part.

Brass foundries at central shops have about held their own, but iron foundries have decreased. Arc welding was a major factor in reducing the number of cast-iron parts made at the mines.



Arc welding, starting about 1919, now is an accepted maintenance practice

Since 1911, bent-back-wire socketing with or without zinc or babbitt has been almost entirely replaced by straight-wire zinc socketing, and the thimble-and-clamp attachment has been applied to large ropes, such as on skip hoists. In 1926, the thimble-and-clamp attachment was being used on both the 1⅛-in. auxiliary shaft and 2-in. main skip ropes at New Orient mine, Illinois, while plans for a skip hoist at the new No. 22 mine, Island Creek Coal Co., West Virginia, included the same type of hitching.

Repair work has gravitated more and more to the central shop, where conditions, tools, availability of materials and specialized workmen favor better results. Complete overhaul-

Improved electrical materials are back of one of the outstanding achievements in reducing maintenance. Materials such as Transite, Bakelite, Micarta and fiber board have come into more general use as substitutes for the easily charred wood as a mounting base for contacts, and Mycalex (1934) has gained adherents as an insulator because of its ability to resist the nitric acid resulting from electric arcs in closed equipment.

Asbestos-covered wire as a heat-resisting winding, now widely used in heavy-duty motors, first attracted attention in 1924, but for a time afterward lost favor because of lack of understanding of its proper method of use. Recent improvements in the abrasive and dielectric strengths of asbestos have broadened its field of use.

Introduction of Tirex rubber-sheathed cable in 1920 for locomotives and mining machines marked the beginning of a long list of improvements in cables for cutters, drills, loading machines, locomotives and stripping equipment. Jackets have been made tougher by using a higher percentage of Para rubber, compounding with selenium (Simplex) or tellurium (General Electric), vulcanizing under pressure, etc. These tougher rubber jackets, which permit a cable to withstand—without severe damage—being run over by a 10-ton locomotive at full speed, have materially reduced cable maintenance cost. At the same time, improvements in woven-fabric jackets have enabled cables of that type to retain favor for some services.

Breaking of the cast resistance grids on mining machines and locomotives was a major maintenance item in 1911. In 1915, the EMB sherardized drawn-wire resistance was offered, followed a year later by the Post-Glover "Everlasting" grid punched from rolled stock. Other manufacturers followed with edge-wound ribbon or other continuous steel strip, special alloys and numerous other improvements until today resistance failures are a minor item.

Breaker Cuts Repairs

The De-Ion breaker (Westinghouse), available in a few types in 1928, and used at a few mines in 1932, was a major development from the standpoint of reduced maintenance of contactors on motor starters and control switches, and the principle, under license, is now incorporated in the controls offered by a number of manufacturers.

Introduction of the multiple V-belt drive, dating from 1926, has been prominent in the reduction of both mechanical and electrical maintenance, especially where these drives have displaced the open spur gear and pinion. Elimination of the vibration caused by the gearing relieved the motor bearings of a major cause of wear and eased the stress and wear on electrical insulation and connections.

Auxiliary blowers attached to locomotive motors have reduced maintenance of that equipment by preventing roasting of the insulation and the melting and escape of bearing lubricant. Blowers also have been applied to excellent advantage on a few hoist motors and substation units.

COAL MINER'S LOT MEASURABLY BETTERED IN LAST QUARTER CENTURY

BY JAMES PRENDERGAST

President, Susquehanna Collieries Co.
Cleveland, Ohio

TECHNICAL DEVELOPMENTS and improved working and living conditions in the coal-mining industry have made notable progress during the last quarter of a century. My earliest recollections of mining hark back to the days when the hand-pick system ruled. Then came the air puncher, which latter gave way to the undercutting machine. Still later the shortwall machine appeared. All these changes, of course, took place while the hand-loading system continued. Now we witness complete mechanization both of cutting and loading.

Haulage systems, too, have undergone marked changes. I recall the mule gathering to the main parting where the coal was hauled by spike teams to the outside. Later the main haulage was done by wire rope and compressed-air and steam locomotives. These were eventually displaced on main haulage by the electric locomotive and finally full mechanical haulage was installed. My earliest recollections as to power go back to steam—once the almost universal source of mine power. Steam was supplemented by long air lines. Now electric generation and transmission hold sway.

Preparation Was Simple

When I review the changes which have taken place in the preparation field, I think first of the old two-track tipples with their 1¼-in. gravity bar screens. Coal passed directly from the screens into railroad cars, with such preparation as the trimmer would give it as the coal came into the cars. Eventually the multiple-size screens came into being with conveyors which handle coal as gently as eggs, and full mechanical separation of the coal from impurities now takes place.

In the matter of working conditions many outstanding advancements come to mind. In the old days we worked nine hours and it was a common sight in the winter months to see the men coming to work before daylight with smoky, dirty oil lamps on their caps. These lamps gave an uncertain, flickering light and the smoke mixing with the coal dust at the working face brought about a very uncertain illumination. But that was not the whole story. The oil seeped from the lamps and the oil container all over the caps and eventually onto the clothes of the miner.

In time these oil lamps were replaced by the carbide lamp. Although the latter required a great deal of attention, it was a wonderful improvement, both in light and in cleanliness, over the older lamps. Eventually we arrived at the electric cap lamp, which has topped all other forms of illumination with its steady, powerful light.

JAMES PRENDERGAST

Has been watching coal-mining developments with keen eyes for many years. Before joining the Susquehanna Collieries Co. organization, which he has headed since 1928, Mr. Prendergast had a long background of experience in the Ohio bituminous fields, both at the mines and in sales and executive capacities. So the impressions of the changing scene which he sets down in this brief story are impressions not specifically of either the anthracite or the bituminous branches but of the industry as a whole. Mr. Prendergast was born in Columbus, Ohio, in 1882 and in the early days of his coal-trade career was associated with the Morris Coal Co. and the Baltimore & Ohio Coal Co.

In the old days, the mine worker dressed at home in his dirty clothes, which often were damp and exceedingly cold during the winter season, came back home at night after a hard day's labor in clothes reeking with perspiration, chilled to the bone, to then wash in a washhouse with a fire newly started. It was quite an experience indeed. One of the finest improvements in mining has been the installation of bathhouses at the mines, where the clothes are well dried and adequate supplies of hot and cold water are available in well-heated buildings.

Working Hours Cut

The working hours have been reduced from nine to eight and now to seven hours per day with a five-day week practically universal in the mines. This has made available long hours for recreation—in marked contrast to the situation which prevailed in former times. In the old days, many employees lived four or five miles from the mines and they would walk this distance to and from their work. Today they come to work in automobiles and one of the present problems of mine management is to provide parking space for the cars of the workers.

What has been the outstanding technical achievement in mining during these years? Personally I am impressed by the extensive change to mechanization. This, of course, has been forced upon the mining companies by the increasing wage scales paid. The extent of mechanization in the future, therefore, will depend entirely on the amount of the increase in wages paid to labor. In practically every coal field of the country, the coal which could be won the most cheaply already has been mined out, and today we are working thinner and poorer veins not touched by our earlier operations.

CHANGING INDUSTRIAL RELATIONS

CHANGES in industrial relations in coal mining during the last 25 years have been no less sweeping, and at times no less violent, than those which have taken place in the economic status of the industry in that period. This is not surprising because labor plays such a dominant rôle in mining that any major change in the economic situation must inevitably have repercussions on working and living conditions. The clashes which have grown out of some of these changes between men fighting bitterly to protect or increase basic wage rates and men struggling desperately to salvage the remnants of their investment in operating properties have been front-page news. These occasional outbursts of industrial warfare and morbid stories of mine disasters have contributed materially to giving the general public a distorted and unfavorable picture of a great basic industry.

Long Uptrend for Miner

With direct labor charges absorbing a larger proportion of the gross income than in any other major industry, that the mine worker should have been called upon to share the misfortunes of the industry as well as to participate in its bonanza days was inevitable. But, while labor has suffered with coal-mining capital on the down swings, the gains won in more prosperous times never have been completely wiped out and the long-time trend has been distinctly one of improvement. A striking example of this is found in the length of the established working day. In 1911, less than 63 per cent of the bituminous mine workers were employed at operations where the 8-hour day was standard. Yet, at the depth of the depression in 1932, when the power of organized labor in the coal fields was at a low ebb, approximately 92 per cent of the workers were in mines recognizing the 8-hour day.

After a slight recession between 1912 and 1914, the proportion began to climb until it reached 97.1 per cent in 1920. From this peak there was a gradual decline until 1930, when the figure had dropped to 92.4 per cent; it rose again in 1931 to 93.0 per cent. These percentages, it should be noted, are based upon figures which exclude the small number of mines that failed to report the length of their working day to the U. S. Bureau of Mines or that changed that length during the year. During the first nine months of 1933, the percentage was 92.6; following widespread recognition of the United Mine Workers and the signing of the Appalachian basic wage agreement, the percentage for the last quarter of the year jumped to 99.8; the average for the entire year was 94.4 per cent.

A double reduction in working time went into effect early in 1934; the number of hours per day was reduced from eight to seven and the number of days which the same force normally might work in any one week was cut from six to five. At the same time hourly rates were advanced to levels which not only yielded the workers the same pay for the 7-hour day which they had received for eight hours but, in many fields, carried increases over the former daily rates. A picture of the effect these changes had on mine labor costs per ton is presented in Table I. The present anthracite wage agreement contemplates the adoption of the 35-hour week in the hard-coal fields next May. This adoption, however, is subject to the right of the operator to work the same crew six days per week for any twelve weeks in a contract year.

On the income side, however, the picture of the mine worker's status during periods of internal distress or general industrial depression has been less happy. Like the operator, he has been compelled to take it on the chin—hard. Reductions in base rates of pay where such rates were not covered by contract and decline in employment opportunities have characterized such periods in the bituminous fields. At the bottom of the depression in 1932, for example, the U. S. Bureau of Labor Statistics' index of payrolls in the soft-coal industry had dropped to 35.6 per cent of the 1929 figure. Total wage payments in 1929, according to the U. S. Bureau of Census returns, were $574,000,000. Since 1932, however, employment has increased and base wage rates have been sharply advanced. The index figure for 1933 was 37.8; the next year it jumped to 54.2; last year it was 58.2.

Base rates of pay in the anthracite division of the industry have been rising steadily for more than 30 years. Hours, too, have been reduced from the 10-hour standard which prevailed at the beginning of the century to an 8-hour standard, with a 7-hour day in the offing. Labor has paid the penalty of a declining market in this field in shrinkage in the volume of employment and reduction in the number of days worked. The total number of men employed in the hard-coal region dropped from 152,000 in 1929 to slightly more than 100,000 last year;

A MODERN WONDER

• Improvement in the standard of living of the employees has been the outstanding achievement of the industry during the past quarter of a century. As I look back on the mining towns I knew thirty years ago, the conditions and the earnings of the miners and the possibilities for an enjoyable livelihood, I see a tremendous change that has taken place.

• The hours of work have almost been cut in two. Wages have been increased 100 to 200 per cent. Housing has been vastly improved and the addition of conveniences, the ability to purchase semi-luxuries, the ability to travel beyond the confines of the coal towns due to the improvement in roads and in automobiles have so completely changed the miner's life and outlook that it might be classed as one of the wonders of modern industrialization.

—John C. Cosgrove, President,
West Virginia Coal & Coke Corporation.

Table I—Effect of Shorter Hours and Higher Wage Rates On Mine Labor Costs

Area	Increase or *Decrease* in Tonnage Per cent	Labor Costs per Ton: Nov. 1933 to Jan. 1934	Labor Costs per Ton: Nov. 1934 to Jan. 1935	Increase in Labor Cost Per cent
Division I				
Eastern Subdivision	*2.0*	$1.0518	$1.2889	22.54
Maryland	*14.3*	1.1318	1.3072	15.50
Upper Potomac	10.9	1.1340	1.3293	17.22
Western Pennsylvania	*8.0*	.9933	1.1855	19.35
Northern West Virginia	*13.2*	.7761	.9908	27.66
Ohio	9.5	.9605	1.1521	19.95
Michigan	*10.0*	1.5770	1.8335	16.27
West Virginia Panhandle	*1.2*	.9747	1.1476	17.74
Southern Low-Volatile*	5.2	.9493	1.1562	21.80
Southern High-Volatile*	*10.4*	.8826	1.0968	24.27
Total†	*5.5*	.9425	1.1578	22.84
Division II				
Indiana deep mines	*5.2*	.7672	.8077	5.28
Indiana strip mines	*2.9*	.3644	.4281	17.48
Total Indiana	*5.1*	.6202	.6689	7.85
Illinois deep mines	12.1	.8647	.9528	10.19
Illinois strip mines	10.8	.3543	.4537	22.41
Total Illinois	11.9	.7828	.8694	11.06
Total — Indiana–Illinois	**7.9**	.7392	.8211	11.08
Division III				
Alabama, Southern Tennessee and Georgia‡	7.5	1.1345	1.3862	22.19

* Comparison for months of December and January only; data for November, 1934, not available.
† Excludes western Kentucky. Comparison for months of December and January only because of lack of November data for Southern subdivisions.
‡ Comparison for months of November and December; January, 1935, data not available.
(Source: Reports to Bituminous Coal Code Section, NRA).

at the peak of employment, back in 1914, the number was 180,000. The index of payrolls in 1935 was 47.5 per cent of the 1929 base.

Improvement in working conditions has not been limited to the reduction in maximum working hours. The progressive mechanization of the various phases of operation also has contributed materially. "Fifty years ago," to quote David Ingle, Sr., veteran Indiana operator, "most of the coal produced in this country was hewn and blasted out of the seam by miners who were skilled craftsmen, expert with the coal pick and the hand auger. They were paid only for the lump coal produced and received nothing for the slack, which then was a useless byproduct. Many of the mines were shut down for several months in the summer season; the employees expected it and gardened during that period.

"Twenty-five years ago coal still was shot off the solid, but the hand pick as a tool of skill and the hand auger were rapidly fading out of the picture. The undercutting machine was making heavy inroads, the post drill was becoming a necessity and electric locomotives for main haulage were becoming fairly common, although mules were still gathering up the coal into the partings. Shaker screens were rapidly replacing the old bar screens, development of the mechanical stokers was creating a little market for the hitherto useless slack and union miners were singing a song entitled 'Nearer Mine-Run to Thee' to the operators at the biennial wage conferences."

At present, the mechanization drive, particularly in the bituminous districts, is centered on the job generally conceded to be among the most arduous in the mines—hand loading. When the U. S. Bureau of Mines first began collecting statistics on the percentage of the bituminous production loaded mechanically underground, the total was less than 0.5 per cent. That was in 1923. By 1934, the proportion had risen to 12.2 per cent and reports of sales of new equipment in 1935 and 1936 point to further substantial increases in the quantity of coal so loaded. In 1934, 19.1 per cent of the tonnage of deep-mined Pennsylvania anthracite was mechanically loaded.

In addition to lightening the actual physical labor involved, mechanization also yields important social byproducts. Where mechanical loading is employed, the traditional isolation of the miner and his buddy in a room with infrequent contacts with their fellow workers gives way to the larger loading-machine crew. The group spirit is given an opportunity for normal development. Friendly rivalry between different crews is promoted. These rivalries—poles removed from the obnoxious speed-up system—are reflected in increased efficiency and improved morale. Moreover, according to some operators who have been closely following the mechanization movement, this group work attracts highly desirable, mechanically inclined younger men to whom the older mining system makes no appeal.

Notwithstanding the increasing use of the machine in mining, direct labor costs, as before stated, continue to be the largest item on the bituminous cost sheet—except at stripping operations. Exclusive of sales and administrative expenses, reports to the Bituminous Coal Code Section of NRA for the ten months ended January, 1935, showed that labor costs approximated 60 to 67 per cent of the total production cost at deep operations. Separate figures on strip mining are not available for

that period, but earlier compilations prior to the adoption of the 7-hour day showed labor charges approximating 33 to 38 per cent of the total production costs. In the anthracite region it is estimated that labor charges represent approximately 85 per cent of the cost of mining.

Census figures for 1929 showed that wage payments in the bituminous division of the industry that year represented 59.5 per cent of the value of the product at the mines; for the anthracite division, the figure was 59.8 per cent. These percentages naturally are lower than those given in the preceding paragraph, where the figures relate solely to mine production costs. In addition, "value of the product" f.o.b. mine or factory, as used by the Census Bureau, includes any profits or capital charges reported as well as the cost of production. The average paid out in wages by the 48 largest manufacturing industries in 1929 was only 18.2 per cent of the value of the products made; steam-railroad repair shops headed this list with 49.8 per cent, wholesale meat packing brought up the rear with 4.8 per cent. The same year Class I railroads paid out 45.2 per cent of their operating revenue in wages.

Hard Coal Field Firmly Union

Since the early days of the present century, labor in the hard-coal region has been tightly organized. Although the Anthracite Coal Strike Commission of 1902 flatly rejected the demand for a closed shop, present pressure by union members has effectively reversed that decision. Button strikes—walkouts when workers appeared at the collieries without the badge of paid-up membership in the United Mine Workers—played a leading part in the reversal. Today, union dues are checked off by operators. During the past quarter of a century there have been a number of major and several minor suspensions arising out of delays in negotiating new contracts and disputes over wages and working conditions. But at no time in that period has the dominance of the union been seriously challenged or even questioned by management.

Organized labor as represented by the United Mine Workers has had a much more checkered career in the bituminous fields. Its early strength was in the old Central Competitive Field (Illinois, Indiana, Ohio and western Pennsylvania) where operators had encouraged the negotiaton of a joint interstate agreement. The Southwest, Iowa, part of the Rocky Mountain region and central Pennsylvania also acknowledged its sway back in 1911, when *Coal Age* was started, but its shadowy hold in the South was even then in jeopardy. The World War brought new fields into its fold and rewon, albeit reluctantly in some cases, certain other districts that at one time or another had recognized the union. As a result, when the 1922 strike broke, the union was able to tie up 73 per cent of the soft-coal production. That show of strength, however, and insistence in maintaining 1920 wage bases accelerated the disintegration which had been foreshadowed by the earlier desertion of some of its war brides. By 1933, its empire had dwindled to Illinois, Indiana, Iowa, part of the Southwest, part of the Rocky Mountain region and a few scattering operations in other States.

Today the power of the United Mine Workers is greater than at any time previous in its history. Outside of the Harlan (Kentucky) district, part of western Kentucky, North Dakota and Texas, a few isolated operations in other sections and the group of mines in Illinois recognizing a rival ogranization (the Progressive Miners' Union) it dominates the scene. The advent of NRA and Washington pressure to force an agreement in the Appalachian region, which now has replaced the shattered Central Competitive Field as the basic wage-making area, helped in this recovery and expansion. But the attitude of the coal operators themselves was equally important. Many welcomed organization in 1933 because the experiences of the preceding decade had convinced them that a strong union was needed to stabilize wages and working conditions.

Industry Not Close-Fisted

Although coal operating groups in the past have fought bitterly for the establishment of wage scales which would permit them to survive growing competition, the industry as a whole has no low-wage complex. On the contrary, the disposition has been one of sharing generously with the workers when there was anything to share or even a hope that there might be. So today finds the industry cheerfully paying the highest wages—with one exception—in its history. That exception was the 1920-1927 scale with its basic day rate of $7.50. And the maintenance of that scale, which was far from universal in its application, almost wrecked organized labor in the bituminous industry.

ACCIDENT PREVENTION MAKES HEADWAY

IN THE early days of the American coal industry, fatality rates probably were much higher than in recent years, even though, as in early European mining, explosions were infrequent. With no mining laws, no inspectors, little technical training and a constant strain to obtain a large tonnage day by day regardless of tomorrow, much opportunity for accident presented itself despite the absence of methane. Disregarding the explosion at the Spencer mine, at Pottsville, Pa., February, 1847, in which seven men were killed, the first three mine explosions recorded all occurred, according to the U. S. Bureau of Mines, in the small but gassy Richmond basin in Virginia. Thus, 40 men were killed at the Black Heath explosion, March 18, 1839; 19 at the Chesterfield mine, in 1854, and 55 at Midlothian in 1855. Being in a small field away from other mining centers, these explosions had little effect on mining practice.

When, however, 179 men were killed in a mine fire at the Avondale mine, at Plymouth, Pa., Sept. 6, 1869, legislation was enacted which established the inspection service in Pennsylvania and compelled the operators of that State to observe certain rules of good practice such as already had been made obligatory in Great Britain. Other States soon began to follow the lead of the premier mining State. For a while, the total number of fatalities of all kinds per thousand employees throughout the Union dropped remarkably. This decline ended about 1878, when the toll per thousand had fallen one-half, though in 1880, after a rise, it was still lower. Thereafter, the record remained practically unchanged until the beginning of the present century.

A Month of Terror

In Dec. 1, 1907, the Naomi explosion, Fayette City, Pa., killed 34 men, and five days later 361 died in the explosion at Nos. 6 and 8 mines, Monongah, W. Va. After a ten-day pause, an explosion at Yolande, Ala., took 56 lives; only five days passed, and Darr mine, at Jacobs Creek, Pa., exploded with a loss of 239 men, and a fifth explosion—at Bernal, Carthage, N. M.—occurred twelve days later and killed 11 men. Thus the nation and the mining population were thoroughly aroused. Out of this came an expansion of the activities of the Technological Branch of the U. S. Geological Survey—later to be reborn as the U. S. Bureau of Mines.

The Geological Survey had started larger-scale testing and analyzing of coal and began studies in coal cleaning in 1904. This led to the establishment of a Technological Branch, on April 2, 1907. J. A. Holmes, chief of the new branch, sensed the possibility of aiding the industry in reducing fatalities. In 1908, the activities of the Technological Branch, by reason of the stupendous explosion mortality of the winter of 1907, were extended so as to cover "the protection of the lives of miners." Stations were equipped with mine-rescue apparatus and manned with a personnel trained in first aid and rescue methods. These were built at Pittsburgh, Pa., and Urbana, Ill., in 1908, and additional stations were added in 1909 at Knoxville, Tenn., and Seattle, Wash. On May 6, 1910, the U. S. Bureau of Mines was established.

But the anthracite companies, the Red Cross and the Y.M.C.A. had not been idle. In this they followed the St. John Ambulance Association, of Great Britain (founded in 1880), the Samariter Verein, of Germany, and the railroads of the United States. Back in 1891, Thomas Boundy in Jermyn, Pa., then a medical student, had written a story entitled "Martin Diamond's Ambition, a Tale of the Mines," in which a boy who had studied medicine was instrumental, by reason of his studies, in saving two or three lives. Dr. M. J. Shields, of Jermyn, revised the story, which appeared in the *Jermyn Press*. From this story arose the first-aid movement in America. In December, 1899, Dr. Shields organized a mine first-aid corps at Jermyn. Together, Shields and Boundy published, in 1900, a First-Aid Handbook. Dr. Shields became later a lieutenant of the U. S. Medical Corps under Major Charles Lynch, of the Red Cross, and toured the country in a Red Cross railroad car, teaching first aid.

First Aid Takes Root

Meantime the coal companies became interested. In 1904, the Philadelphia & Reading Coal & Iron Co. provided lectures on technical subjects for its men, including three addresses by Dr. George Halberstadt, of Pottsville, Pa., on first aid; the next year Capt. W. A. May, of the Pennsylvania Coal Co., employed Dr. Shields to organize a first-aid corps at each of its mines. The Reading then organized its first-aid training. Soon the companies were holding large company first-aid meets. The Hillside Coal & Iron Co. and the Pennsylvania Coal Co. held its first meeting in 1906, the Philadelphia & Reading in or before 1909, and the Susquehanna Coal Co., with its three subsidiaries, in 1910. Leaders in those days were Dr. Shields, Dr. Halberstadt, Dr. J. M. Maurer, of the Susquehanna, and Dr. J. B. Mahon, of the Pennsylvania. The first inter-company meet for the Northern anthracite field was held in 1909.

First aid in 1911 had made limited progress at bituminous coal mines, though, as fast as the U. S. Bureau of Mines established stations, first-aid and mine-rescue methods were taught. Thus, at the close of 1911, the men of the Colorado Fuel & Iron Co., who had received training since November, 1910, held their first annual helmet and first-aid meet in Trinidad, Colo.

First among safety lighting devices was the Spedding steel mill,

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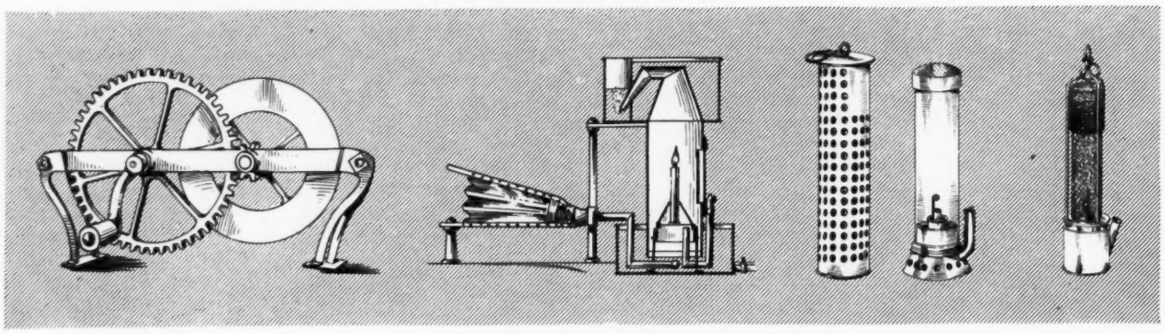
• In 1870, per million tons mined, 13.47 lives were lost; in 1911, 5.35 lives; and in 1934, 2.94 lives. Based per thousand employed in 1870, 5.93 fatalities occurred; in 1911, 3.65; and in 1934, 2.16. Based on thousand 300-day workers, the number of fatalities in 1911 was 4.97 and in 1934, 3.54. Figures for 1935 are not taken because they still are subject to revision. But, viewed in any way, safety has increased. The last 25 years have been the hardest in which to beat the record, for natural hazards have multiplied and, after more than a 60-per-cent reduction had been made between 1870 and 1911, further progress in accident reduction was difficult though studies of conditions and recent records show that much still remains to be done.



Spedding mill, 1750 | Clanny "bellows" lamp | Geordie cover and lamp | Davy lamp, 1817

invented about 1750, though rotting fish skins sometimes had been hung up to afford a faint glow in the dark. In the Spedding mill, a firestone was pressed against a steel wheel, revolved at high speed by a crank, and the sparks resulting afforded a feeble light which was not only costly but unsafe as well, for the sparks occasionally ignited gas.

Dr. W. R. Clanny, a retired ship's surgeon, who had been working on the lighting problem since 1808, succeeded in 1812 in making a lamp that did not explode gas and reported that fact to the Royal Society, of London, England, in May 20, 1813. This lamp, which was used in the Harrington Mill pit, was closed at top and bottom by open water tanks; air was pumped into the combustion chamber by bellows and had to pass through the water on entering and leaving. In latter years, however, the Clanny lamp had a single gauze, bonneted or unbonneted, and the flame was surrounded by a glass cylinder.

A safety lamp was invented later by Wilhelm Nieman in 1813, but it was little used. On Oct. 21, 1815, George Stephenson perfected his lamp and on Nov. 9 of the same year, Sir Humphrey Davy, the physicist, published, in the *Transactions of the Royal Society*, his first experiments on the production of a safety lamp. Because of Davy's standing, he usually gets the major credit, though the earlier Stephenson lamp (known after the first name of the inventor, "Geordie") gave good service and was by some preferred to the Davy lamp.

In the Stephenson lamp, the heated gases of combustion were cooled by passing them through perforated metal plates. Davy's lamp had a gauze for the same purpose. Both lamps are safe if not kept so long in gas as to become hot and if the air current is not too rapid. The Davy may still be in use, though the Bureau of Mines and the laws of some States rightly have condemned it. These earlier types were followed by a number of others—including the Maraut, Pieler, Chesneau, Gray, Ashworth - Hepplewhite, Clowes, Tombelaine, Hughes, Chance and the Beard-Mackie indicator—some of which were used in this country. But the type most prevalent in the United States was the Wolf.

Originally miners in this country depended upon oil and paraffin lamps for working illumination. By 1911, however, the acetylene open-flame lamp had practically driven its older rivals out of the mines. In 1908, the Philadelphia & Reading Coal & Iron Co. began experiments for the development of an electric lamp and later produced one described by J. T. Jennings, electrical engineer of that company, September, 1911. It had a Hirsch-type cell with two electrolytes on a horizontal plane; the plates were separated by a combination of wood fiber and perforated hard rubber. Gelatinous silicic acid treated with an acid formed a gel 30 minutes after charging, solidifying the electrolyte. The battery weighed 2 lb. and would supply a 3-c.p. lamp at 2 volts for 12 to 14 hours. Furnished with a reflector, the lamp was mounted on a miner's cap, and the battery usually was supported on the hip.

Coal Dust a New Hazard

In the earlier years of mining, coal dust probably took little part in explosions, because coal was dug by hand tools, explosives were not used and the dust at the face must have been relatively coarse. Methods of underground transportation, however, favored abrasion, especially at the foot of the shaft, where the corves, or baskets, were filled and hoisted, many of them leaking as they rose in the shaft. After Walls End (Newcastle) explosion on Sept. 3, 1803, John Buddle suggested that coal dust might have been a contributing cause, because men in the mine were burned by ignited dust particles. Faraday and Lyell in 1845, de Souich in France in 1855, and others expressed a conviction that coal dust played a part in mine explosions, and Verpilleux, between 1864 and 1867, tested its flammability. Vital, in 1875, actually attempted to discover the pressures such explosions would develop, and declared that a blow-out shot might ignite a gassy dust.

After making small-gallery tests, Marreco, at Elswick, England, in December, 1875, decided that coal dust without methane could be exploded, but Galloway, after experimenting, concluded in December of the following year that a little methane was necessary to aid in the action. Hall, however, in 1876, after large-scale tests in a mine entrance, substantiated Marreco. Sir Frederick Abel, in 1880 made small-gallery tests and asserted the contrary and that firedamp played a determinative part in coal-dust explosions, with which Mallard and Le Chatelier agreed in 1882 after their tests were concluded. The British Royal Commission of 1866 admitted that highly flammable coal in large quantity might be exploded without firedamp by a blow-out shot.

After experiments with a long surface gallery, the Prussian Firedamp Commission in 1884, without admitting that coal dust could be exploded in a methane-free atmosphere, declared that certain coal dusts would extend an explosion even into areas where no coal was available. In 1886, the Austrian Mine Explosion Commission stated that 100 grammes of dynamite would ignite coal dust. The same year, W. H. and J. B. Atkinson announced their conclusion that certain explosions they had investigated were caused solely by ignition of coal dust. The British Mines Act of 1887 required watering in dry and dusty places for a distance of 20 yd. from each shot.

Apparently not until 1887, when a coroner's jury put the entire blame for the Altoft explosion on coal dust,

was rock-dusting suggested. Speaking before the Illinois Mining Institute six years later, George S. Rice suggested that natural clay dust had limited the area ravaged by the explosion which occurred at Pekay mine, in Iowa, Feb. 14, 1893.

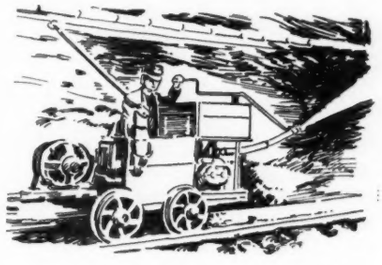
German and French commissions continued to urge that firedamp was an invariable initiating cause of explosions. To settle these problems, galleries were constructed in Liévin, France, by J. Taffanel; at Altofts colliery, in England, by W. E. Garforth in 1906, and again in 1908 by the Coal Owners' Association; at Pittsburgh, Pa., by the Technological Branch, U. S. Geological Survey, in 1908, and at Herne, by the Westphalian Syndicate. Finally, the Bruceton (Pa.) experimental mine was started in December, 1910, by the U. S. Bureau of Mines. The Altofts mine was rock-dusted in 1907, and well before 1911 Mons. Taffanel had designed his rock-dust barrier which was then quite generally introduced in the mines on the continent of Europe to limit the extension of explosions. Twenty-five years ago, expert opinion generally favored the belief that coal dust in itself was explosive and that rock dust would suppress an explosion of coal dust when started, but in the mines of the rank and file of the industry, extreme doubt was prevalent.

Rescue Apparatus

Breathing apparatus a quarter century ago lacked little but details to render it really safe and effective. The helmet of Prof. Swann, of the University of Liége, Belgium, devised in 1853, was the first equipment to attempt the regeneration of exhaled air. Little was done by Swann to perfect the mechanism of his helmet. In 1899, the Giersberg apparatus was introduced by the Berlin Fire Department and improved in 1901. A set of this type was purchased by the Nova Scotia Steel & Coal Co., Sydney Mines, N.S., the first rescue apparatus to be brought to this continent.

Heinrich Draeger, of Lubeck, Germany, took over the Giersberg equipment in 1903 and made several improvements in its construction. Fifteen Draeger equipments were brought to this country in 1907; the first four of which were purchased by the Anaconda Copper Mining Co. for its Butte copper mines. In September of the following year, Draeger apparatus was installed by the Technological Branch of the U. S. Geological Survey. These had metal helmets, twin oxygen cylinders and air regenerators, and double breathing bags direct-connected to the helmets. In December, 1911, the United States had 988 Draeger rescue equipments out of a total of 4,983 throughout the world. In the field were the Aerolith, Fluess, Meco, Weg, Aerophor, and the several Servus equipments. In the 25 years that have elapsed a process of elimination has wiped out all but the compressed-oxygen types of apparatus, and improvements have been made in details of construction.

Viewing the wonderful reduction in accident rate following the Avondale disaster and the legislation and inspection soon thereafter instituted, the U. S. Bureau of Mines doubtless looked for wonderful results from its intensive campaign for safety. It is true there were no more months of dire gloom like December, 1907, but neither did the fatality rate lessen greatly, as had been hoped. Mines were opening where hazards were greater; they were getting larger, and the more men in a mine the greater hazard to every man employed, for each man by an indiscretion can involve all the others in a disaster; they were about to use new and untried machinery and the miners were trying to get pay for all coal mined, run-of-mine and slack, and whenever they got their demand proceeded to shoot coal off the solid with consequent formation of fine coal dust. But, in keeping the records for all fatalities where it was, the Bureau made a remarkable contribution to the mining industry.



First rock-dust machine—1911

Toward the close of 1911 the Bureau of Mines had already seven fully equipped rescue cars—one each at Wilkes-Barre, Pa.; Trinidad, Colo.; Evansville, Ind.; Rock Springs, Wyo.; Billings, Mont.; Huntington, W. Va., and Pittsburgh, Pa., and six rescue stations, one each at Pittsburgh, Pa.; Knoxville, Tenn.; Birmingham, Ala.; Urbana, Ill.; McAlester, Okla., and Seattle, Wash. Illinois and Kentucky also had such stations and Illinois had mine-rescue cars. In addition, probably 50 mining companies were maintaining rescue stations.

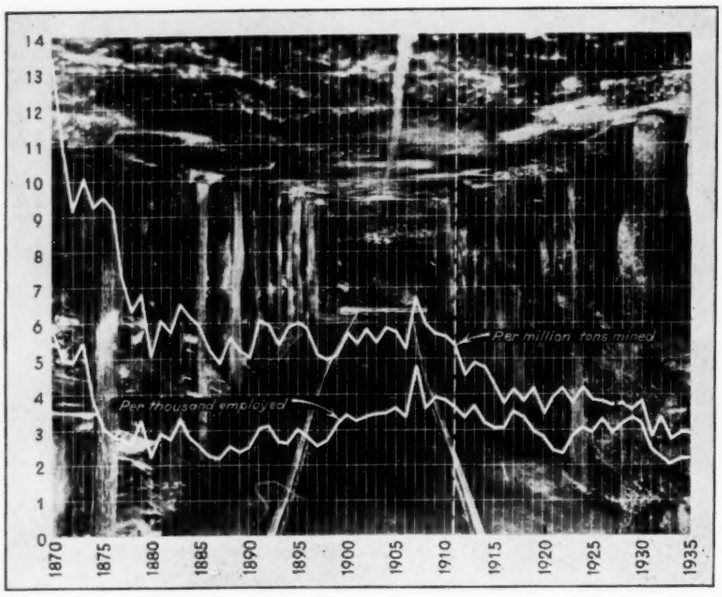
Perhaps the first to demand in this country that coal dust be laid with water was Peter Hanraty, one of the earliest shotfirers in Indian Territory (1884). Convinced unwillingly that coal dust without methane could be ignited by a shot, he insisted that dust be sprinkled. He also humidified the mine air with the pump exhaust.

Sprinkling Begins

Prior to the big explosion in the Savannah mine (I.T.), April 12, 1885, William Clarke used a water cart to dampen the roads in that mine. Joseph Watson, superintendent, Como No. 5 mine, Como, Park County, Colo., sprinkled his mine with water from pipes laid along the headings, May, 1895. Every room had its hose connection. He was the first to employ shotfirers in Colorado. Eastern mines apparently were slow in using water, but at the Consolidation Coal Co.'s mines, sprinkling cars with small centrifugal pumps and hand nozzles were being used in 1908. On May 5 of that year, A. E. Wood made application for a patent for the use of water on cutter bars, which was granted Jan. 5, 1909. In or before 1906, the Rockwood mine-water car was devised at Rockwood, Tenn., by Richards & Sylvester, for use in the mines of that company. Such cars were later manufactured by S. B. Stine & Son. They held 300 gal., and a pump operated by the movement of the car sprayed headings with water. Early users were the Victor Fuel Co. (1907), United States Coal & Coke Co. (1908) and American Fuel Co. (1909).

Intakes were preheated with exhaust steam, not only by Peter Hanraty but also by Carl Scholz, at No. 8 Shaft, Hartshorne, Okla., either in 1911 or 1912, the latter not only to prevent explosions but to avoid drying of shales in the winter. About 1915, C. R. Stahl put about 1,000 ft. of 4-in. pipe radiators along both sides of the intake in the Glen White mine of the E. E. White Coal Co. Exhaust steam from the steam pumps was turned into the air after it had received this initial heat. Later a 4-in. pipe was run down the shaft to carry additional exhaust steam to the intake. Still later, the radiators were eliminated.

Perhaps the first to use rock dust in the United States was the Victor-American Fuel Co., at Delagua, Colo., in March, 1911. Adobe dust



Accidents per thousand employed and per million tons mined drop

was placed on shelving near the roof and at the side of the roadway. Some was thrown around promiscuously with the hand shovel. However, G. B. Pryde, then general superintendent, Union Pacific Coal Co., put 8 to 12 in. of dust on the floor of Reliance No. 1 mine, probably in 1911, and let the men spread it around as they traveled the road. Not knowing how much free silica the adobe dust might contain or how harmful it might prove to the lungs of the workmen, the practice was discontinued.

Short-flame explosives, blasting batteries and caps had also been introduced. Great Britain had used ammonium-nitrate explosives since 1887, but in this country their manufacture seems to date from 1904, when the Masurite Co. commenced to make an explosive of that name. E. I. duPont de Nemours & Co. placed Nihilite on the market and in the latter part of 1907 embarked in the manufacture of the short-flame product on a large scale. Masurite was declared "permissible" May 1, 1909. About 1908, the duPont company introduced Monobel and Carbonite, after a test lasting about six years. Today there are 154 explosives on the permissible list of the U. S. Bureau of Mines.

Mine inspection by company men had also made progress. The company inspectors of the Consolidation Coal Co. by 1908 were reporting their readings with the Wolf safety lamp, aneroid barometer, water gage and wet-and-dry thermometer and taking can samples of the mine atmosphere.

A National Mine Safety Demonstration was held by the Bureau of Mines on Oct. 30, 1911, at the Arsenal in Pittsburgh, Pa., and an explosion of coal dust, unmixed with methane, was staged at the experimental mine, Bruceton, Pa. It proved unexpectedly violent, burning the surrounding woods. On the following day, 40 teams competed in a first-aid contest.

On Sept. 23, 1912, a National Mine-Rescue and First-Aid Conference was called at Pittsburgh, Pa., to formulate rules relative to the conduct of mine rescue and first aid.

To carry on the work of holding such national competitions and safety conferences, the American Mine Safety Association was formed and held its first important meeting in Pittsburgh, Sept. 22-24, 1913, in which 35 teams were entered, all but two from Pennsylvania. After an abortive business and exhibition meeting in New York City, a successful meet was held at Terre Haute, Ind., Sept. 11 of the next year. But operating companies were evidently not desirous of sending men to any more national meets and preferred their own State meets, so on July 15, 1915, decision was reached at Sewickley, Pa., to merge the association in the Mining Section of the National Safety Council.

Early efforts in promoting safety after October, 1911, were directed mainly to a reduction of fatalities from explosions, which had possibilities even more sinister than falls of roof if not curbed. All other problems were subordinated to this interest. About the first development was the introduction of the rock-dusting machine at the mines of the Victor-American Fuel Co., by W. J. Murray, vice-president, in 1912. A number of others were soon after devised in the Rocky Mountain field, but in the East rock-dusting played a minor part as compared with humidification and sprinkling or drenching with water. The Union Pacific Coal Co. at Superior, Wyo., probably was the first to sprinkle mine cars.

In 1915, the Pittsburgh Coal Co. started rock-dusting, spreading the dust by hand at the Banning mine. Old Ben Coal Corporation initiated the use of rock dust in Illinois in the winter of 1917, using barriers and developing a power distributor in 1924. The work of J. E. Jones, who had these protective devices in his charge and later toured the country urging better rock-dust protection, did much to advance the practice of rock-dusting, which was made compulsory in Utah in July of the latter year.

On Jan. 15, 1925, a survey showed that 32 companies had rock-dusted in all 400 miles of roadway, five of whom ground their own dust, one used adobe dust and one both the latter dust and concentrator tailings. High-pressure dusters made their appearance in the West about 1924, the first of which probably was installed at Castle Gate, Utah, by the Utah Fuel Co., which also probably was the first to use the dust in airways as well as roadways. A high-pressure rock-duster was placed on the market by the Mine Safety Appliances Co. about August, 1928. Some coal companies in the West used portable crushers for making dust, glowing it on the mine surfaces as made, a method devised by Samuel Tescher, general superintendent, Royal Fuel Co., for the Royal mine at Aguilar, Colo., in 1924.

Still More Dust Needed

In the following year the Pittsburgh Coal Co. developed a rock-dusting machine with a funneled outlet, which later was placed on the market. Alabama had a broad rock-dusting campaign in 1925. West Virginia rock-dusted its first mine the same year. In 1933 a survey showed that in the previous year 73,000,000 lb. of rock dust was used in the United States by 382 mines out of 5,629 operating.

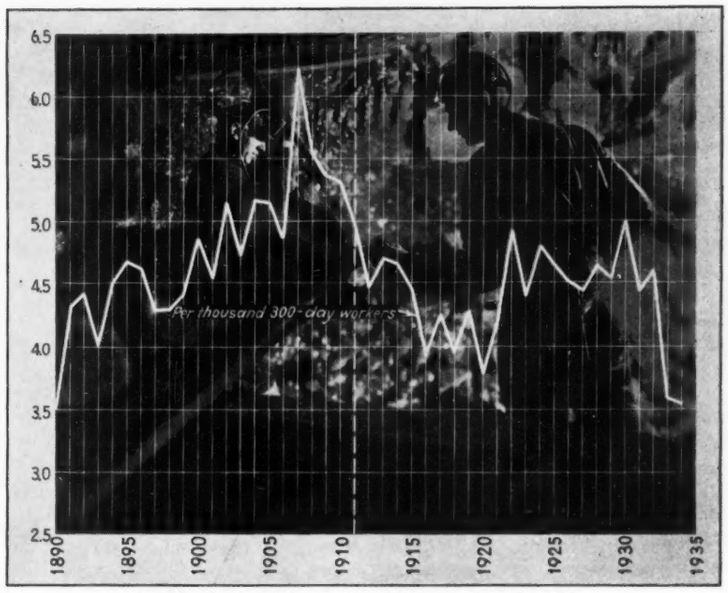
John Crawford, State Industrial Commissioner of Utah, between 1918 and 1920 induced one of the companies in Utah to use water on the cutter bar, and since then many mines in the West have provided for its use.

About 1922, the Tennessee Coal, Iron & R.R. Co. commenced this practice, and later no one was permitted to cut coal without it. The two developments were not related to one another, nor to the earlier patent of Mr. Wood. Other companies, notably the H. C. Frick Coke Co., have used it extensively.

Soon after the U. S. Bureau of Mines was formed, a few men lost their lives in rescue work from defective apparatus, and the Bureau endeavored to find the cause of the accidents. J. W. Paul discovered that death was due in one case to injector failure. In 1915 the Bureau developed an apparatus named the Gibbs apparatus after its deviser, W. E. Gibbs, who had been working on it since January, 1914. It was not, however, put in general use until late in 1918. This apparatus did not waste oxygen when the wearer was idle, had an improved carbon-dioxide absorber, liberated little heat and used caustic soda instead of caustic potash. The Bureau early became convinced that the helmet was an undesirable part of the breathing apparatus and advocated the mouthpiece and nose clip, and in 1917 definitely denounced the helmet. In 1916 Paul developed the first apparatus to provide positive pressure on the breathing bag: Anaconda Copper Mining Co. and Cleveland-Cliffs

Iron Co. were among the first to use it.

Acting under the Department of Scientific and Industrial Research (British), the late Henry Briggs, Heriot-Watt College, Edinburgh, Scotland, about July, 1920, perfected what was known as the Briggs apparatus. Experiments by George McCaa, of U. S. Bureau of Mines, about 1920 made possible a lighter equipment with a lessened risk of failure of the parts and ended in the construction of McCaa apparatus. A new McCaa breathing apparatus appeared in May, 1927.



Accidents per thousand 300-day workers decline

Bernard Draeger designed a portable self-rescuer utilizing a small compressed-oxygen flask and, in 1914, the Draeger Oxygen Apparatus Co. offered a 6½-lb. apparatus with regenerator, oxygen flask and breathing bag, good for 30 to 45 minutes. The flask, however, made it unduly heavy. After the All-Service Gas Mask was perfected in 1921, and used for fire fighting and rescue work in moderately noxious gas where oxygen was present in quantities to support life, it was natural that the self-rescuers should embody the same principle with charcoal to remove carbon dioxide, calcium chloride to eliminate moisture and Hopcalite to furnish protection against carbon monoxide. Hopcalite was a true war baby, being developed by a Johns Hopkins man and a University of California man to protect gunners from that gas when in revolving turrets fouled by gunfire. The self-rescuer, light, foolproof, stable as long as sealed and safely usable for a half hour, was extensively introduced. Thus the 6½-lb. Draeger unit was replaced by a self-rescuer weighing 13 oz. Gas masks were fitted with a speaking diaphragm facepiece by the Mine Safety Appliances Co. in March, 1934.

About October, 1913, the Lungmotor made its appearance. Resuscitation, originally intended only for asphyxiation by carbon dioxide, was extended to those whom electric shock had incapacitated, certainly prior to 1913. A majority of the doctors favored the Sylvester method of resuscitation in 1911, but by 1915 the Schaefer method had been generally adopted, and the report of the Committee on Resuscitation advocated the Schaefer method and condemned Draeger's pulmotor. But with oxygen replaced by Carbogen, a mixture of oxygen with 5 or more per cent of carbon dioxide, and an inhaler, or Inhalator, the method was read back into the church later by one of the very physicians, Yandall Henderson, who had banned it in 1915, and since then it has had universal acceptance where available.

Electric Lamps Progress

Electric safety lamps made steady progress after 1911. The Philadelphia & Reading Coal & Iron Co. had 500 on March 30, 1912, and 4,000 Hirsch electric lamps were in use in the anthracite region by the middle of that year. In 1914, 15,000 were declared to be in service by V. H. Manning, director, U. S. Bureau of Mines; twice that number in 1915 and six times that number (90,000) at the close of 1916, and the number was increasing 2,000 per week.

About 1911 the British Briggs lamp appeared. This had a loop of copper wire on a brass stalk that, being turned into the lamp, made it non-luminous so that the blue cap readily could be discerned if firedamp was present. This lamp thus served both for lighting and gas inspection. Concurrently, the Cunyngham-Cadman gas detector made its appearance. It has a sheet of asbestos soaked in salt or bicarbonate of soda which was moved parallel with the flame, almost crossing the wick. It made a big yellow cap, the length

of which testified to the percentage of methane present. About the same time, V. B. Nesfield, Bignour, United Provinces, India, devised a filtering tube which by a mercury column measured the osmosis of the gas and so its methane percentage.

Ceag hand lamps received the first prize in the British Home Office awards in 1912. Their crowning merit was spiral springs which broke the electric contact whenever the bulb was broken. The Ceag lamp was the first to receive the Bureau of Mines approval, June 3, 1913. About 1912, the Edison lamp appeared and won the Rathenau medal of the American Museum of Safety. The principle under which safety, despite breakage of the lamp bulb, was obtained being established, several lamps were constructed in accordance therewith and accordingly were approved by the Bureau of Mines—Wico, of the Witherbee Igniter Co., then used by the Philadelphia & Reading; Bulldog, of the Maxivolt Primary Battery Co., and Hirsch, of the Hirsch Electric Mine Lamp Co., all in 1913. The trip lamp of the Portable Lamp & Equipment Co. appeared in June, 1931.

Mule lamps were introduced in January, 1915, and in May of that year, the first a Hirsch lamp and the second a Wico. The Hirsch lamp carried not only a light but a horn to warn the miners of the mule's silent approach, the device being credited to Douglas, a stable boss of the New River Consolidated Colliery Co., Eccles, W. Va. In August, 1915, the Manlight electric safety lamp for application to the miner's cap was introduced; the Wheat electric lamp was announced by the Koehler Manufacturing Co. in January, 1919.

Candlepower Increased

Many new models of the Edison, Wheat and Super-Wheat have appeared and increased the lighting power of the lamps. With the shortened hours which lamps now have to run, a better light can be afforded without exhausting the battery, but improvements in batteries, lamps and reflectors have more to do with the increased candlepower now obtained. Still shorter hours, as now provided, bid fair to result in further improvement. Use of a second smaller bulb for emergencies, introduction of magnetic locks for bateries and the gas-filled bulb are other improvements.

Recent years have seen the development of three detecting devices in this country. In 1927 the United Carbide & Carbon Co. offered a firedamp detector which depends on the resistance of an electrically heated wire as modified by the presence of methane, which increases the temperature. The same year, Mine Safety Appliances Co. also announced a continuous methane recorder. A sensitive methane indicator was devised in the laboratories of the U. S. Bureau of Mines in 1935 and presented for use at the close of the year. It consists of a thermostatic coil placed over the axis of the flame of a round-wick safety lamp and so arranged that an increase in heat due to the presence of methane will cause rotation of the foot of the coil, so that the quantity of gas can be read on a scale.

Many improvements have been made in blasting materials and practices. Black powder is now sold largely in cartridge form, being known as pellet powder, thus eliminating the powder keg with its dangers, the manufacture of cartridges and making it possible to use a definite charge. It was introduced by E. I. duPont de Nemours & Co. in April, 1926. Cardox, Energy Air Miner and Airdox were other safety provisions (see p. 408). Plugs as substitutes for stemming were revived in 1935 (over a century after their first use) with the Voortman plug of the Safety Stemming Plug Co. and the Heitzman plug of the Heitzman Safety Blasting Plug Co. They give a more secure stemming and therefore greater safety. Permissible explosives have had a largely increased use.

A new factor in the safety campaign entered with the compensation acts passed in 1914 and following years, which largely displaced the "common servant" provision in the common law. This was followed at the close of 1915 by a plan by which the Associated Companies under H. M. Wilson provided for inspection and rating of mines so that those which complied with certain safety provisions and organized their forces for safety received lower premium rates than those which made no such provisions. As the rates increased the desire of operators to obtain lower rates induced more and more of them to improve working conditions.

Interest in minor accidents increased, and frequency and severity rates were studied assiduously. Interest in eye accidents was evidenced by the adaptation by Strong, Kennard & Nutt Co. of the Resistal safety lens, Dec. 15, 1917, for miners' use. This was of the safety-glass type with two layers of glass having celluloid between them. The wire-screened Adjusto goggles followed in October, 1916, manufactured by the same company, and a wire-screen goggle made by the Mine Safety Appliances Co. in July, 1926, and one produced by E. D. Bullard in January, 1927. These goggles were not any too well received by the mine workers and have given place, at least in most cases, to the glass goggle of increased strength. Finally, the Union Pacific Coal Co., in 1933, had the American Optical Co. test the eyes of its entire force and fit refractive-lens goggles with side screens to mechanical repair men and without side screens to all others. Many men were found who had extremely defective vision.

Safety Hats Adopted

Protective hats were worn in the mines of Cornwall, England, for a great many years. They were made of cloth and heavily impregnated and coated with wax. The earliest protective hats used in this country were of this type and manufactured by E. D. Bullard. After the War, the Anaconda Copper Mining Co. conceived the idea of giving every man a hat similar to a trench helmet but weighing only 7 oz. A protective hat of molded Bakelite was produced by M.S.A. about August, 1930; the Cool Cap of the Portable Lamp & Equipment Co. with a corrugated canopy top and ventilation through the corrugations dates from February, 1933, and the Skullgard of M.S.A. from May of that year. Shoes with a protective toe also were introduced and are now extensively in use.

Notable events were the formation

in January, 1917, of the J. A. Holmes Safety-First Association, named after the first Director of the Bureau of Mines, who died Jan. 13, 1915. This gives awards for safety achievement and organizes branches of the association for the study of safety methods throughout the country. Another activity of the Bureau, instituted in 1923, was the safety service under which the engineers of the Bureau examined mines for safety and made confidential reports to the owner. The Bureau of Mines established in 1925 the "Sentinels of Safety," annual trophy award for the best record in safety made at coal and metal mines and quarries, provided by the *Explosives Engineer*. It also has given training in first aid. At many mines all the men have received the training. On July 1, 1925, the Bureau initiated a graduate course in mine rescue in charge of its Safety Extension Service and on Oct. 21, of the next year, published a basis for the classification of mines according to gas content.

An outstanding development in the promotion of safety was the appointment of four electrical inspectors in Pennsylvania, Oct. 2, 1928, to inspect all permissible and flameproof electric machinery in that State, to report on its condition and have all defects corrected.

PAST TRIUMPHS OVER ADVERSE CONDITIONS CAN BE REPEATED TODAY

By ERSKINE RAMSAY

Chairman of the Board
Alabama By-Products Corporation
Birmingham, Ala.

"I HAVE no lamp to guide my feet but the lamp of experience; I know of no way to judge the future but by the past." So said a famous American on a famous occasion, and so I am taking that statement as my text in trying to show that we can and shall meet and overcome the difficulties of today just as we always have done in days gone by when the problems were just as great as they are now. I will be rather personal in this story to tell it as I see it.

At the time of my birth, my father worked in a coal mine in the Pittsburgh district near what is now the great steel town of Homestead. From there we moved to Shafton, Pa., in the Irwin gas-coal field, where, at this first coal mine shaft sunk in America west of the Alleghenies, my father was employed successively as a miner, hoisting engineer, mine foreman and then for many years as manager of the company until it was absorbed by the Westmoreland Coal Co. In 1881, he went with the Carnegies as superintendent of their Monastery mines and coke works near Latrobe.

During my years at Shafton and the Monastery mines, at one time or another I worked at practically everything in and around the operations. My father—one of the famous Carnegie junior partners—was a great believer in boys working. At the time I became of age I was receiving a salary of $125 per month. Previously, in conformity to the good old Scotch rule, I had turned over all of my wages to my father as earned. The rate of wages I had received had varied from $15 per month and up. I ran a store for the Shafton Cooperative Society for two and one-half years at the $15 monthly stipend. By the time I reached my majority, I had turned over just a little short of $5,000 to my father.

I entered the senior commercial class at St. Vincent College, near Latrobe, in 1882 and was also a member of its engineering class of two pupils. After being graduated at the head of the commercial class in 1883, I immediately resumed my old position as master mechanic at the Monastery works. It was here that I acquired the experience in coal washing which was to prove so helpful to me in later years when the Tennessee Coal, Iron & Railroad Co. changed over from washing no coal at all to washing every pound it coked at its 20 blast furnaces or sold on the open market.

The Carnegies and H. C. Frick combined their coal and coke operations to form the H. C. Frick Coke Co. in 1883, with my father as superintendent of mines and general consulting engineer. He moved to Mount Pleasant and I succeeded him as superintendent and engineer for the Monastery operations. Under my early management, the Monastery plant distinguished itself by making the first Frick record of as much as four tons of coke per oven drawn—and "Frick" ovens had been in operation in the Connellsville coke region for many years!

In 1885, when not quite 21 years old, I was made general superintendent of the Morewood Coke Co., which soon consolidated with the South West Coal & Coke Co., making it the third largest coke corporation in the Connellsville region. The Frick and McClure companies alone were larger. On one of his visits to the mines, Mr. Frick told me that he had sold the year's output of the South West's Morewood operation—the second largest coke plant in the region—for 85c. per net ton f.o.b. railroad cars at the ovens and, while he did not expect to make a profit at such a low figure, he would like at least to break even. We made a profit! We could do this because, excluding royalty and the usual 10c. per ton for supplies and incidentals, the labor cost, including everything in and about the mines and ovens, was only 67c. per net ton of coke f.o.b. cars.

Miner's Wages Low

In those days, there were no tipple scales at coke-region mines; the miner was paid so much per car, including the much controverted "hump." The railroad weights on the coke shipped showed that, with the 67c. labor cost, the miner received a little less than 20c. per net ton for the coal he dug and loaded. This 20c. included all labor of all kinds from the room neck to the face and covered, of course, laying track and timbering. The coal was not undercut in those days, and practically no shooting was done. It was all muscle work and for that reason it was often said that, because of the great amount of shoveling, a miner must at least have a strong back.

Without singling out any particular mine or company, it may be assumed that at the present time in the Connellsville region all labor from the sidetrack to the face is costing, say, 70c. per net ton. With mechanization the job could be done at the same old Morewood cost, or,

in other words, at a reduction under the present cost of approximately 50c. per net ton!

In 1886 I was made assistant engineer of the Frick company in charge, under my father, of the opening of the new Standard shaft and coke-oven plant. Standard quickly became a showplace and model for the region as well as the winner of all competitive medals for output from all other mines of all companies in the Connellsville field. The next year I resigned from the Frick staff to go to Alabama as mining engineer for the Pratt division of the Tennessee Coal, Iron & Railroad Co. This division included all the coal and coke operations of the company in that State.

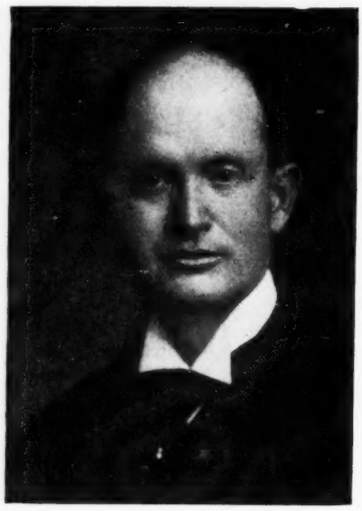
At that time, the financial condition of the Tennessee company was none too rosy. But this was really a blessing in disguise. Because the company was not rolling in money, Tennessee management was compelled to be on the lookout continuously for ways and means to improve the quality of its products while reducing the costs of production. Rigid economy was necessary and the company was forced to plan, build and operate new and better devices at the lowest possible cost. In other words, these things when done always had to be carried out on plans entailing the lowest possible expenditures.

Oven Heat Makes Steam

In endeavoring to meet the situation, the Tennessee Coal, Iron & Railroad Co. was the first operation in Alabama to make steam for its mines by utilizing waste beehive coke-oven heat and gases under its boilers. Making steam from beehive coke ovens had its origin in the Durham district in England, but the Tennessee company was the first American operation to adopt the practice. After the Tennessee company had demonstrated the possibilities of this system, other companies both in Alabama and in other States followed its lead. This steam-making plan was vitally necessary to the Tennessee Coal, Iron & Railroad Co. because at its No. 1 shaft 10 per cent of the output was being burned under boilers to make steam for that one operation. Truly, necessity was the mother of invention.

The first shaking screens to be used at bituminous coal mines in this country were installed at the No. 4 slope mine of the company in 1890. These screens were designed by the Tennessee company and built in its own shops. Installation of screens of this type was necessary to meet changing conditions in sizing and washing so that the slack could be washed for the coke ovens and the nut and lump sizes of coal could be screened out and sold. These screens are now widely used in all mining districts.

Another development pioneered by the Tennessee Coal, Iron & Railroad Co. was the multiple car dumper. The first equipment of this type to be used in this country was designed by me, built in the shops of the Tennessee company and installed at the Smythe ore mine on Red Mountain in 1900. The patent issued on this device covered both multi-car whole-trip dumping and part-trip dumping using swivel couplings, "which make unnecessary uncoupling the cars from each other or from the motive power." In keeping with the patent, I also had designed swivel couplings for rotary dumping of sections of trips to eliminate all uncoupling and recoupling in the dumping operation. These swivel couplings are now very extensively used, even in far-off India.



ERSKINE RAMSAY

Scotch by ancestry, Pennsylvanian by birth and one of the first citizens of Alabama by virtue of almost a half century's participation in its economic and civic life, Mr. Ramsay has been associated with the coal-mining industry since boyhood. He was born at Six Mile Ferry, Pa., in 1864, educated at St. Vincent College and was superintendent of the Frick Monastery mines and coke works before he was 19. His inventions and patents in the field of coal-mining equipment have made history. Mr. Ramsay here draws upon some of his early mining experiences to show how seeming handicaps can be turned into real advantages. The coal industry, he declares, has overcome many adverse conditions in the past; it can and will overcome them today.

Washing Art Was Old

Coal washing already was an old art when I left the Pennsylvania coke region to cast my lot with Alabama. When the Tennessee Coal, Iron & Railroad Co. began to wash all its coal in the early '90s, however, the effects upon the development of both the coal and ore industries of the State were outstanding. The company immediately moved into the front rank in Alabama coke quality and as a purveyor of steam coals—in which the shaking screen played a real part. Adoption of the policy of washing the coal before coking resulted in:

1. Better coke and lower cost. The reduction in costs was due to greatly increased production per oven drawn and to a substantial reduction in the quantity of breeze made at oven doors, in the coke yards, on cars and at the blast furnaces.

2. An improved quality of pig iron which was suitable for making open-hearth steel.

3. Use of large tonnages of Tennessee pig iron at the Carnegie Homestead mill, showing the Tennessee company that it could make steel out of its own Alabama pig iron.

4. Erection and operation of the Ensley steel plant of the Tennessee Coal, Iron & Railroad Co., where the first open-hearth steel to be made on a commercial basis in the South was produced.

5. Construction of the Ensley rail mill, where the first open-hearth steel rails manufactured on a commercial scale in this country were rolled.

6. Abandonment of the use of Bessemer steel for rail making in the United States.

During the time these things were being done by the Tennessee company, I was its chief engineer and assistant general manager. It was my privilege to play a major part in many of these developments. The Tennessee company did a very big thing in a national way in bringing about these changes and deserves a great deal of credit.

Shakespeare says, "Sweet are the uses of adversity." We did many of the things I have mentioned because we were forced to do them. And we can do it again today for the same reason.

PUMPING AND DRAINAGE

EARLY coal mines were opened on side hills and, at first, openings doubtless were made self-draining, but, after a while, dipping seams had to be worked and shafts to be sunk; hence other openings, known as "water gates," were driven to rid the mines of water by gravity, though some water doubtless was carried out in buckets.

In 1354, the monks of Durham, in leasing coal land at Ferry, contracted for the right to make pits and water gates, and in 1486, the Finchdale monks erected a pump at Moorhouse worked by horse power, but it was possibly a bailing arrangement such as was sometimes actuated by a water-wheel. The two illustrations from "De Re Metallica" of George Landmann (Agricola), Chemnitz, Saxony, one showing a suction pump and the other a pump utilizing suction and pressure, both worked by hand, show that in 1556, when Agricola's book was published, the principles of the water pump already were well known.

Hero, in 130 B.C., showed how, by putting pressure on water in a closed tank by the heating of air, the water could be lifted in a pipe into a tank hung from a rope which passed over a pulley. The weight of the water thus transferred to the tank opened the doors of a temple. Giovanni Battista della Porta in 1601 described much the same device as Hero's, but with steam instead of water. He understood also how to suck up water by condensing steam.

Pump Principle Known Early

Solomon de Caus in 1615 forced water up a pipe by heating the vessel from which the pipe projected, and Edward Somerset, marquis of Worcester, in his "Century of Inventions" (1663), described an arrangement that worked like the pulsometer pump, with two egg-shaped chambers alternately filled with steam or perhaps alternately heated and cooled. Perhaps also he used a vacuum. The principle of the pump already was established in that day, and even in della Porta's time, as has been noted.

In 1698 Thomas Savery patented a pump, much like Lord Worcester's, and used both suction and pressure, utilizing steam up to 8 lb. per square inch but it melted the solder joints of his boiler, so that he had to use spelter. Desaguliers condensed the steam by a jet of cold water within the vessel, instead of outside of it. Savery made many pumps for mines and domestic purposes.

Denis Papin, in 1690, raised steam in a boiler, and provided a partially water-filled "cylinder" in which he utilized it, but his cylinder was U-shaped with one leg long and tapered. A piston rested on the water in the larger and shorter leg and, when the steam was up, the valve at the top of the cylinder was opened, whereupon the steam entered above the piston and forced it down with the water beneath it, so that the latter rose in the small leg of the cylinder and flowed out at such a high level that it could be made to turn a waterwheel. Then the steam valve was closed, and the steam in the cylinder was allowed to exhaust through another valve in the cylinder located above the piston, which then rose, drawing feed water through a third valve opened for that purpose, thus completing a cycle.

In the course of pump development through the centuries the steam was gradually divorced from the water to be pumped. Papin had only a piston between them and did not seem to realize that steam engine and pump were mechanisms that should not be combined. However, faulty as it was, Papin's engine may be described as a single-action, noncondensing engine.

Newcomen, an ironmonger, and Cawley, a glazier, with Savary, a Cornish mine owner, in 1705 took the water out from under the piston and admitted steam thereunder which they condensed with a water spray, letting the piston down. By rods and a walking beam, this movement was communicated to the mine pump. Thereafter, pump and steam engine were kept definitely apart, though, eventually, the walking beam—the sole connecting link between them—gave way to simpler arrangements.

In 1713, a boy, Humphrey Potter, to avoid work, made the motion of the beam automatically open and close the valves by cords, which Henry Beighton, five years later, replaced by rod and tappets. In 1725 this Newcomen engine was in general use at coal mines, and though John Smeaton improved some of its later details in 1770, it was not until James Watt, an instrument maker, repaired a model for Glasgow University that the most important change appeared.

Papin cyclically had cooled the boiler or shut off the steam valve; Savery and Newcomen had condensed the steam by water, but Watt provided a condenser apart from both so as to conserve heat, and the modern steam engine was born. Its career and development, where practical, had been as a mine pump. It was a gift of the mining industry to the world, which until then knew of nothing but man power, animal power and the waterwheel.

In 1782, Watt patented double-acting engines and the use of ex-

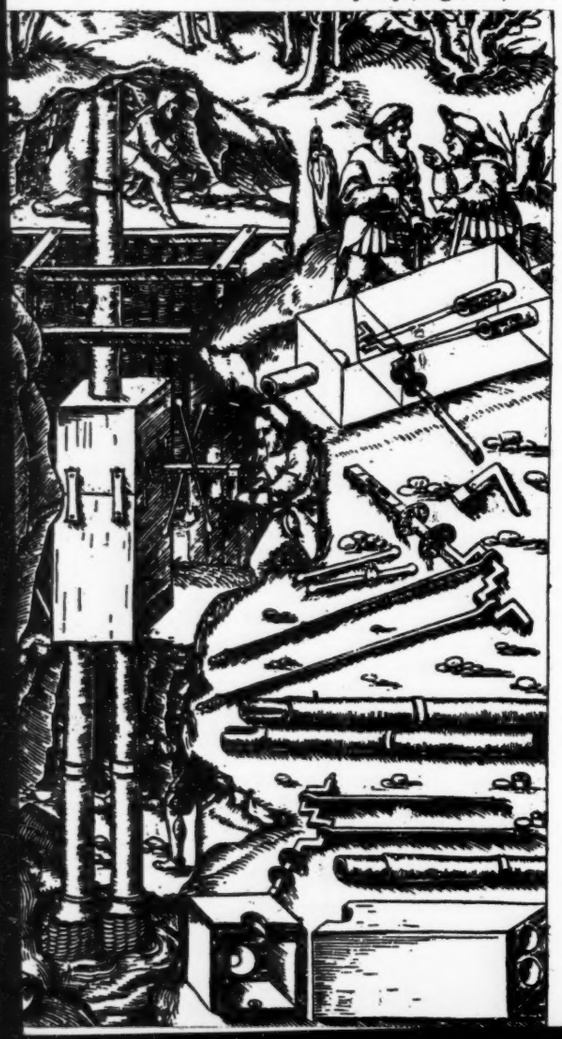
Suction pump, Agricola, 1556

pansive steam, which latter feature he invented in 1769. But Watt never favored a pressure exceeding 7 lb. per square inch, thinking it dangerous. Thus, though Watt, in his first patent, covered the non-condensing engine, his pressures did not justify its use. But Richard Trevithick and Oliver Evans in 1800 used higher pressures for the propulsion of road locomotives (or, rather, motor cars, as they did not run on rails) and as early as 1781 John Hornblower built and patented compound engines.

Woolf's compound engine was introduced at the Cornish mines about 1814, but the high-pressure single-cylinder engine of Trevithick won out, and the Cornish engine—a walking-beam engine that started the lift with high-pressure and completed it with expanded steam—was developed from it, many being erected at mines in the United States. In 1923, the Pennsylvania Coal Co. had still in operation two Cornish pumps at No. 13 shaft, Central colliery (each of 800 g.p.m. capacity), and one such pump of equal capacity at No. 1 shaft, Old Forge colliery.

A later move was to connect pump and engine by a piston or plunger rod, but, with this change, the engine had to join the pump in the mine, both working horizontally. This change involved either putting the boiler plant underground, as did Erskine Ramsay in Alabama, or piping the steam down the shaft. Underground boilers, steam pipes and steam pumps all helped what is termed "natural ventilation," but often caused shaft fires. Also, the exhaust from steam pumps, turned into the mine water, converted its ferrous sulphate into sulphuric acid and caused much corrosion.

Suction and force pumps, Agricola, 1556



According to R. V. Norris, the first water hoist with a special water shaft or water compartment was used in 1896 at the Luke Fidler Colliery, Mineral R. R. & Mining Co., Shamokin, Pa., and the earliest regular water hoisting was with semicircular tanks at the Nanticoke collieries of the Susquehanna Coal Co., designed July, 1880, by J. H. Bowden. However, early in that year, water hoisting was introduced at the Lehigh Navigation Coal Co.'s mines; Coaldale No. 8 and Lansford No. 6 were the earliest of these hoists. These two companies later installed several hoists, as did also the Philadelphia & Reading Coal & Iron Co. and Lehigh Valley Coal Co.

Centrifugals Arrive

Prior to 1911, few coal mines used centrifugal pumps; the recognized method of raising water was by reciprocation. The first centrifugal pumps were single-stage units, and date back in this country to 1818, when what was known as the "Massachusetts pump" was manufactured in Boston.

Mons. Rateau, finding he could obtain a lift of 1,000 ft. only by driving the single-stage impeller at 18,000 r.p.m., realized that such a pump could not lift water with satisfaction from deep mines and introduced the multi-stage unit, manufactured here later by the Southwark Foundry & Machine Co.

Late in 1901 the Delaware, Lackawanna & Western R.R., Coal Department, now Glen Alden Coal Co., installed its first centrifugal pump (perhaps the first in the anthracite region), a Morris 6-in. single-stage cast-bronze unit, 90-ft. head, at Dodge Colliery. In July, 1905, that company placed a 6-stage Worthington centrifugal pump at Hampton Water Shaft, and in September, 1908, installed a 6-stage Allis-Chalmers unit at the same location. These pumps operated at 720 r.p.m. against a 500-ft. head, each pump, direct-connected to a 1,000-hp. 2,300-volt induction motor, delivering 5,000 g.p.m. The Truesdale breaker of the same company installed a 2-stage centrifugal pump in June, 1907. At No. 1 shaft, Kingston Coal Co., a Jeansville 4-stage 125-hp. centrifugal pump was installed on Oct. 1, 1908, to pump a non-gritty, low-acid water. It had a capacity of 800 g.p.m. and worked against a head of 375 ft.

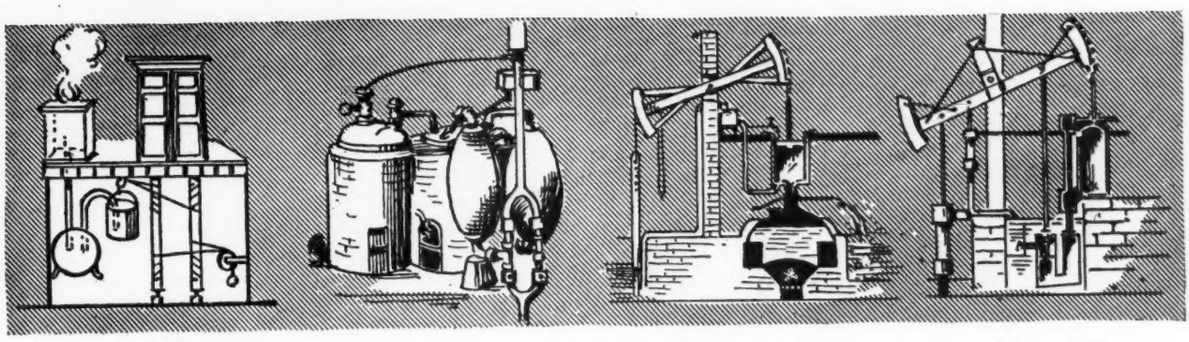
In 1885 Dr. Julius Pohlé was experimenting with the air-lift pump, which he is credited with introducing in 1888. Its simplicity makes it difficult to ascertain where it received its first mine use, but before 1908 it was employed at the Ellison Shaft, Homestake Mining Co., and in March, 1909, the Keystone Coal & Coke Co. appears to have been using it at Greensburg, Pa.

An early triumph of the anthracite industry was the construction, in 1893-1895, of the 15,100-ft. Jeddo tunnel by A. G. Markle & Co., which runs from the Jeddo basin through the Black Creek anticline to the Conyngham Valley. This tunnel was extended at about the same time for a distance of 4,880 ft. at right angles to the main tunnel. Another famous water-drainage rock adit (constructed about 1906) was the Hoffman tunnel, 10,646 ft. long, which ran from the bottom of the Borden Shaft to a point near Clarysville, Md., and provided drainage for many Georges Creek mines, overcoming a lift of 244 ft.

Another water tunnel of note which used only roadways in the coal was that which connected the Forest City mines, Hillside Coal & Iron Co. —now the Pittston Co.—with the Coal Brook mine, Delaware & Hudson Co.—now the Hudson Coal Co. —at Carbondale, Pa., where the water came to the surface.

In July, 1906, the Lehigh Navigation Coal Co. started the Lausanne Tunnel, completing it Feb. 5, 1912. This tunnel ran from Coal Port, near Mauch Chunk, Pa., to a point in the Buck Mountain bed at the No. 2, or Nesquehoning, shaft and was 7,500 ft. long in the rock. It formed part of a project, soon thereafter completed, extending to Tamaqua, Pa., in all 13 miles long, all the rest of which was in a gangway driven in the "B" bed. About the same time the 5,600-ft. Oneida Tunnel No. 1 in Schuylkill County was constructed for the Lehigh Valley Coal Co. It extended from the coal basin to Tomhicken Valley and displaced five pumps.

Since 1911, centrifugal pumping has made great strides, mainly shaft pumping. Reciprocal pumps generally are used where water has to be gathered near the face, though since about 1921 the La Bour pump—a centrifugal pump without a volute—has been quite largely used for that purpose. Many other pumps also



Hero, 130 B. C. Savary, 1702 Newcomen, 1711 Watt, 1774

have been provided for gathering, including Gould and Allis Chalmers units. Centrifugal pumps were early adapted to the removal of flood water. The ease with which they can be moved forward on a receding flood, the small space they occupy and their low cost favor this application. A notable installation was that of the two-stage 2,000-g.p.m. centrifugal pumps to remove 600,000,000 gal. beginning Jan. 27, 1914, from the Shooly mine, Pennsylvania Coal Co., with an ultimate lift of 375 ft., this being done despite the entry of 2,000 g.p.m. Another was the recovery of the Big Muddy Coal & Iron Co.'s mine, where a 1,400-g.p.m. centrifugal pump removed the water from the flood of Nov. 30, 1921, though before the job was finished three steam pumps were recovered and used and three more centrifugals were added which ejected together 7,000,000 gal. daily.

A heavy inpour of water from the Lackawanna River, March 20, 1936, entered the Hallstead colliery and flowed into the Seneca and William A. collieries, Kehoe-Berge Coal Co., near Pittston, Pa., and spread into the No. 9 colliery, Pittston Co. To remove this water, eighteen Barrett-Haentjens 4,000-g.p.m. 350-ft. centrifugal pumps were installed, starting May 12, and are still operating.

To circulate water for jigs and screens large-capacity centrifugal pumps have been constructed. Thus the Glen Alden Coal Co., at Baker breaker, Scranton, Pa., installed two 14,000-g.p.m. centrifugals with only 20-ft. head. Their Francis-type impellers are wide but of small diameter, giving large volume and low head.

A priming device introduced by Barrett, Haentjens & Co. about 1922 afforded an opening for the automatic priming of pumps, first suggested by J. T. Jennings, electrical engineer, P. & R. C. & I. Co., in May of that year and included in the first completely automatic station (p. 442), worked out by Otto Haentjens, B. M. Horter and G. V. Woody in collaboration with Mr. Jennings and installed at P&R's Draper colliery, June, 1923, followed by installations at the Kohinoor and Boston Run collieries of the same company.

Air-lift pumping suffered from the narrowing of the compressed-air field and from its relative inefficiency, especially when wrongly installed. An early use (January, 1913) was at the flooded Crown Hill No. 1 mines, Clinton (Ind.) Coal Co. But still earlier were permanent installations for domestic and boiler-feed water at the mines of the Union Pacific Coal Co., Wyoming.

When the Lackawanna River broke into the Taylor Mine in 1924, the Glen Alden Coal Co. lost its Hampton pump station and four coal beds were submerged. Three air lifts were installed, two with 16-in. pipe and one with 12-in. Between April 30 and Aug. 14, 660,000,000 gal. of water was raised to the Clark bed, from which five 5,000-g.p.m. centrifugal pumps delivered it to the surface.

Features which distinguish the era since 1911 are arrangements providing for sumps enough above the pumproom floor to afford easy suction and the so-called "submersible" pumprooms, bulkheaded so that the water can rise many feet above the pumproom without flooding it.

At an early date, about the year 1896, W. A. Lathrop had a submersible pumproom constructed for the Stockton mine of the Lehigh Valley Coal Co., at Hazleton Shaft. Entrance was provided from the surface. At Forest City, Pa., the Hillside Coal & Iron Co. used a rock slope from the Clark bed to the Second Dunmore bed and placed its pumproom in this lower seam. Water had to rise 117 ft. to get into the pumproom, which contained two 6-stage centrifugal pumps lifting 2,000 g.p.m. against a 300-ft. head. Another centrifugal pump in the same chamber had a capacity of 1,000 g.p.m.

A similar pumproom was provided at the Law Shaft of the Central colliery, near Old Forge, Pa., by the Pennsylvania Coal Co. It was approached by a slope and the water could rise 40 ft. without drowning the pump. The Jermyn pump station of the Hudson Coal Co., put in service in 1925, has a similar provision. It is 270 ft. below the surface and is approached by a 690-ft. slope excavated in solid rock, with a gradient of 39 per cent. The chamber, 181 ft. long, 22 ft. wide and 30 ft. high, with a wing 12x40 and 17 ft. high, has eight electric centrifugal pumps which together deliver 33,000 g.p.m. via a 36-in. pipe.

Deep-well pumps probably made their appearance at coal mines by 1913, but the first of which record is available was used by A. W. Spaht, Old Ben Coal Corporation, at Christopher, Ill., who put the motor in a tower on the surface and the pump level of the Big Muddy River to lift the water to a storage tank. In this way, no matter how high the river rose, the pump motor remained unsubmerged. In 1926, a deep-well pump was used at the Bartley (W. Va.) mine, Pond Creek Pocahontas Coal Co., to lift sludge out of the sump, the motor being near the lower landing level. Perhaps an earlier application was that of two 42-in. impeller single-stage 750 r.p.m. 90-ft. head pumps used in Carbondale (Pa.) No. 3 section, Powderly mine, Hudson Coal Co., each pumping 5,000 g.p.m. Drives were 250-hp. 2,300-volt vertical motors on the surface.

Many means have been used to prevent corrosion and wear in pumps in the last 25 years. Tobin bronze (58:40:2 copper-zinc-tin alloy) was used for all parts exposed to acid mine water. Wood lining for all parts but the valve-pot covers persisted for many years. Monel metal (copper-nickel alloy) valves arrived about 1924. The Glen Alden Coal Co. used bronze (75:10:15 copper, tin and lead) for all parts coming

in contact with acid water, and others followed suit. Glyco metal also was used at some plants for impellers.

In May, 1923, the Pittsburgh Coal Co. used Kosmos porcelain plungers on a 5½x8-in. triplex Aldrich pump operating against a 239-ft. head, and the Deming company in 1924 introduced a pump with a vitreous china cylinder and a bronze valve chest, making valve chambers and piston rods of anti-acid bronze or chrome iron, and valve springs, and sometimes the cylinder, of Monel metal. High-silicon steels were used for wearing rings and impellers about 1927. Ascaloy (a chrome-manganese steel), Duraloy (a chrome-iron alloy) and Cimet (a chrome-nickel-iron alloy) were used for linings of reciprocating pumps. About 1928, manganese steel was used for shell, impeller and disk of centrifugal pumps, and stainless steel (chrome-carbon-iron alloy) for piston rods.

Much progress has been made in meeting pipe corrosion since 1911. About 1912, so unsatisfactory was pipe material that the Delaware, Lackawanna & Western R. R., Coal Department, at Storrs No. 1 mine, Scranton, Pa., put the acid water through 520 ft. of coal up a slope of 12 deg. Crosscuts were made in the side of the slope 70 ft. apart and, with a special tool, holes 2 ft. square were made in line from the end of one crosscut to the end of the next; up this improvised pipe the water was pumped. The crosscuts were closed by brick and concrete.

About 1914, a firm in Boston, Mass., began to manufacture cement-lined pipe, feeding it in with a press and pushing out most of it with a train of coned cylinders. The Stanton Ironworks Co. of England made a similar pipe about 1924 by placing the cement in the pipe and revolving the latter, and about 1928 the American Cast Iron Pipe Co. introduced Simplex cement-lined cast-iron pipe in America, similarly made, with the lining $\frac{1}{16}$ in. thick.

H. W. Johns-Manville Co., in February, 1914, reported that some of its fiber pipe had been used for carrying acid water. Bermico, a pipe of indurated fiber, was introduced by the Fiber Pipe Co. about 1921, and several Illinois firms had used it by October of that year for water drainage, and the Bell & Zoller Coal & Mining Co. for carrying electric cable. Later, manufactured by the Brown Co., it was made of wood fiber and heated for 6 hours under pressure in pitch asphalt. Hard-rubber pipe was introduced by the American Hard Rubber Co. in 1930. This rubber was first used for nipples by the South-East Coal Co., Seco, Ky.; for pipe by the Helvetia Coal Mining Co., Waterman, Pa., and as a lining for pipe by the Pittsburgh Terminal Coal Co., that same year.

Several large water tunnels were built in the last quarter century, including a second Oneida tunnel, 7,030 ft. long, parallel to the first and about a mile distant. It eliminated twenty pumps. Starting at the foot of No. 5 slope in the Buck Mountain bed, it ends near Nuremberg, Pa., in the Tomhicken Valley. Operations began at the inside end on April 16, 1912, and at the Nuremberg end on May 19 of that year. The tunnel was completed July 7, 1913.

A tunnel that was driven at the beginning of the mine operations it was intended to serve was the 3,808-ft. 7x12-ft. haulage and drainage cross-measure tunnel at the Weston colliery, Locust Mountain Coal Co. It tapped practically the bottom of the Little Buck Mountain measures. By its early driving—June, 1913-February, 1914—it met the problems of haulage and drainage and was not an afterthought added too late to serve for the full life of the mine.

A third tunnel was an extension of the offset from the first Jeddo tunnel and was 3,500 ft. long. Another extension of 4,100 ft. was made in 1930. On Sept. 8, 1934, a long cross-measure water tunnel was holed through from No. 40 shaft of the Lehigh Valley Coal Co. at Hazleton to this drainage system. A similar cross-measure tunnel was commenced in February, 1928, by the Lehigh & Wilkes-Barre Coal Co. The tunnel, completed June, 1931, empties into Catawissa Creek and is 16,150 ft. long.

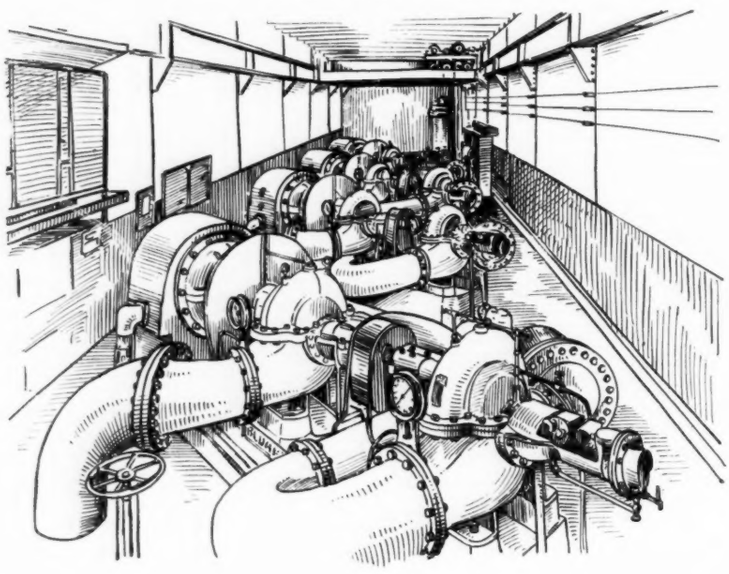
Natalie Tunnels

A combined drainage and haulage system of 12,000 ft. in cross-measure tunnels was constructed by the Colonial Colliery Co. between the Greenough and Natalie mines and the new Colonial breaker. The tunnel to the Greenough workings is 3,500 ft. long; that to Natalie, 1,550 ft. long. A drainage tunnel, 5,700 ft. long, was driven to the surface. Other connections in the rock were made near the shaft. Extensive water tunnels also have been constructed at the Philadelphia & Reading Coal & Iron Co. mines.

In the bituminous region, extensive drainage systems have been constructed, but relatively few drainage rock tunnels. These systems grew with advance of years, and are sometimes not only of great extent but somewhat elaborate construction. In 1925 the United States Coal & Coke Co. had at Gary, W. Va., 7 miles of tunnels; one system, 37,200 ft. long, drained Nos. 9, 7, 6 and 12 mines, and the other Nos. 10, 3 and 1. Wherever places were to be caved and drainage kept intact, ditches 4 ft. wide and 2 ft. deep were dug in the mine floor. Concrete was placed at the sides and on top.

The Consolidation Coal Co. has constructed five miles of ditches to the Hoffman tunnel (already described) and the Allegany water system, consisting of 6,000 ft. of ditch and 3,000 ft. of tunnel, drains the north end of the Georges, Creek field.

Jermyn pump station



THE FUTURE: WHAT DOES 1936-61 PROMISE IN MINING DEVELOPMENTS?

By JOHN A. GARCIA

President, Allen & Garcia Co., Chicago, Ill.

WHAT does the future promise in coal-mining technical developments? The question recalls a visit Floyd Parsons, first editor of *Coal Age*, paid me 25 years ago, shortly after our own company had been organized. Had I told him then what I thought might happen in the industry between 1911 and 1936 he doubtless would have considered me a fit candidate for Matteawan. But, remembering the great advances actually made during that period, I am going to risk peeking into the crystal globe and describing some of the probable changes visioned there for the next quarter of a century.

JOHN A. GARCIA

Who by invitation of the editors here assumes the difficult task of prophetic projection, launched his own consulting engineering and construction company in association with the late Andrews Allen the same year that Coal Age was born. Following his graduation from the Missouri School of Mines and Metallurgy in 1900, he spent three years in metal mining, chemical work and railroad construction. Mr. Garcia definitely cast his lot with coal mining in 1903, when he took the position of mining engineer with the mining department of the Missouri Pacific R.R. He then became successively chief engineer for the Rock Island Coal Mining Co. in what was then Indian Territory, Consolidated Coal Co. of St. Louis, Dering Coal Co., Burnwell Coal Co. and Consolidated Indiana Coal Co. Since the organization of the Allen & Garcia Co., Mr. Garcia and his associates have been prominently identified with the design and construction of many outstanding coal-mining properties throughout the country.

In the preparation of coal at the face, there will be practically no solid shooting. There should be considerable progress toward safer shooting with elimination of dust, windy shots, etc. I also expect to see mechanical stemming—that is, the tamping will be done by some mechanical means rather than fireclay.

In mechanical loading, there will, of course, be continuous developments, most of them toward simplification and strengthening of the machine—and perhaps a few radical new types of loaders. The big improvement will be made in reducing the time lost in changing cars—possibly by loading onto conveyors, which will discharge in a continuous trip in the entry, but certainly large-capacity mine cars. These cars will have solid ends and be unloaded either by overturning cages or rotary dumps. They certainly will have automatic or semi-automatic couplings and the dangerous three-link hitching will be abolished—either by common action or by law.

Use of treated ties on main lines and use of steel ties in rooms and for spacers in entries will be universal. Heavier rail and much better track alignment and grading will be common practice, since transportation is such a vital factor in the success of mechanical loading.

In timbering there will be a steady increase in the use of steel. Since the invention of the hitch drill, many mines are rapidly going to steel crossbars in the entries and, in some instances, steel lagging made out of old rail. Steel timbering in the entries is permanent, makes for safety and there is practically no maintenance cost after first installation. Steel also will be used in room panels because it is possible to recover the steel when the panel is worked out. There has been no change in method of room timbering since mining was first begun. Props are used today as they were at the start and are quite an item on the cost sheet. I look for the use of steel framework in rooms, not only because of its safety but ultimate low cost—assuming methods are developed for recovery when the rooms are worked out.

The underground workings will be designed by engineers and each section foreman will be furnished a detail sheet showing how his area is to be worked and all places will be driven on sight. Instead of a survey once every six months or a year, surveyors will be in constant employ in the entire underground workings driven systematically by survey and under engineering supervision.

One of the most radical changes I saw in the aforementioned crystal was the substitution of internal combustion engines, like the diesel, for the trolley locomotive. When this haulage system is accomplished it will be possible to use alternating current for all mine machinery, excepting a few small motor-generator sets for charging storage-battery locomotives. Some progress already has been made with the diesel engine for underground service in Europe. Although the mining laws in most States prohibit the use of internal combustion engines underground, I feel sure that when it is proved that this method of haulage is as safe as or safer than trolley haul, then the laws may be changed.

Most of our mining laws need changing, or at least codification. They differ so radically in the various States, and often without reason, that the present generation should arrange to codify them and bring them in conformity with modern conditions and methods.

Mining systems will change toward the use of multiple entries and in efforts to have the mine workings conform to the loading machines' requirements rather than vice

versa, as was attempted when loading machines were first installed. This change will be made not only for improved ventilation but to facilitate haulage, provide more place for car storage, thus speeding up car changes—and with steel timbering and no yardage costs, the ultimate result will be less expensive than the present two-entry system which is common in the majority of mines.

On the surface the trend undoubtedly is toward better preparation. With the rapid increase in the use of domestic stokers, the smaller sizes will have a much larger market and there will be a consequent decrease in demand for lump. Some solution must be found to the fines problem, either by briquetting or by devising a practical way of shipping and burning this material as well as sludge from washeries. At those mines where the water supply is ample, I look for a trend away from purchased power and the utilization of some or all of the mine product too low in fuel value for shipment.

Perhaps most of the above is visionary rather than vision, but, if one should judge the future by the past, it is not unreasonable to expect these and possibly many other improvements in the art of mining and processing coal.

THE COAL INDUSTRY LOOKS AT THE RECORD

THE RECORD of the coal-mining industry on the economic front during the past quarter of a century has been replete with triumphs and defeats, with sharp setbacks and sharper recoveries. Each shift has been a spur to further technical development which has been motivated both by the drive to increase production in the boom days and the pressure to reduce costs in the indigo hours. The result of this interplay of forces has been the record of engineering and managerial achievements epitomized in the preceding pages of this issue.

But how does the industry itself regard this record? How does it rate the significance of the changes which have taken place during that period? Along what lines does it look for the greatest technical advances in the next 25 years? Will these advances be merely intensification of trends already plain or will they strike out in entirely new directions? To find an answer to these questions, *Coal Age* asked a group of operating executives and engineers how they would evaluate these changes. The replies to the editorial queries are summarized in this symposium.

Regardless of the particular district in which they may operate, few fail to place mechanization at the top of the list of major technical developments in the past quarter century. There is general agreement, too, that mechanization in its latest manifestation—underground loading—will progress still more rapidly in the future because the combination of high basic wage rates and the competition of rival sources of energy makes mine-cost reductions imperative. Electrification and preparation also rank high on the list. Accident prevention is very much to the fore in Western comments.

Management, as L. E. Young, vice-president, Pittsburgh Coal Co., emphasizes, has not stood still. "While much may be said about the increased use of power and the installation of various types of mining machines, these improvements are only part of a large program. The successful use of cutting and loading machines requires good management. The concentration of work possible when machinery is employed underground has placed an added value on good track, clean roads, adequate ventilation, coordination of effort. These items in themselves do not represent innovations, but new values have been placed upon them in their relation to the operations as a whole.

"Successful management today is a 'thinking' management that analyzes every operation to discover how it may be improved and made more effective in the whole plan of production. Modern management is making savings by eliminating waste of all kinds, including waste of materials, waste of power, waste of effort and waste of labor. The elimination of waste may take many forms: it may be seen in the reduction of narrow work, reduction in idle track, reduction in labor incident to the rehandling of supplies, and the walking of needless miles by officials, repair men and day labor; reduction in idle time by mine cars and other equipment and reduction of idle time of working places.

"Progress at last is being made in securing continuing operations underground. During 24 hours per day and 365 days per year, mines must be pumped, ventilated and maintained. These costs go on when production ceases, and neglect in pumping and maintenance results in damage to property, hazards to employees and increased costs. Multiple shifting, concentration of work and intensive mining probably have resulted in economies as great as any of those resulting from the changes in the strictly mechanical technique of coal mining. These advancements can be secured only by good management in the most modern sense of the word."

Multiple shifting as one of the lines along which future progress should be made has many advocates. The importance of management also is stressed by many. "While not strictly a technical development," says Paul Weir, vice-president, Bell & Zoller Coal & Mining Co., "the item of organization commands much attention. A new generation of mining men who think in terms of production methods rather than in terms of longwall vs. room-and-pillar is growing up in the industry. With the very recent wonderful developments in mining machinery, we find available dependable machines for practically every job. The application of the machines is a problem of organization. Success depends more upon organization than upon machines."

Seek New Uses for Coal

Study of the chemical composition of coal to find new fuel usages for certain coals is among the important developments which should be mentioned, in the opinion of C. A. Cabell, president, Carbon Fuel Co., who envisions further progress in cleaning and in the utilization of coal in the future. John C. Cosgrove, president, West Virginia Coal & Coke Corporation, is another executive who thinks that "the greatest progress within the next 25 years is to be expected from the application of coal to a greater diversified market brought about through research."

Higher labor costs and increasing mechanization, says Charles C. Dickinson, president, Dickinson Fuel Co., will have the secondary effect of centralizing output in larger producing units. "In short, we seem to be headed toward fewer mines, fewer laborers and, unless the present tend-

ency to increase the cost of labor and subsidize the construction of hydroelectric plants is stopped, we may expect decreased production of coal." Further mechanization and labor displacement where physical characteristics are not limiting factors also is foreseen by Arthur B. Stewart, president, Davis Coal & Coke Co. These views also are held by many other operators.

Change from hand to machine mining and the increased specialization in inside mine labor stand out in the developments of the past 25 years, says W. P. Tams, president, Gulf Smokeless Coal Co. These changes have opened the door to greater employment of less skilled labor, since the miner of today no longer is required to do many of the things his predecessor did, such as laying track, handling slate and undercutting with a pick.

Lauds Electric Applications

General application of electric power for cutting, haulage, lighting and pumping is rated first among the technical developments of the period under review by R. A. Nowlin, mining engineer, Crozer Coal & Coke Co. "Electric power thus applied has changed and cheapened former methods, making the cycle of the various details of mining generally complete from working face to railroad car." Use of the carbide lamp, adds John J. Lincoln, vice-president of the Crozer company, has been a real help during these years in working and in reducing accidents by giving more light with which to examine the roof. The new electric mine lamps still further improve this situation.

This same point with respect to improved lighting and safety also is emphasized by a number of coal-company officials. Rock-dusting, too, comes into the safety picture. The safety measures worked out by the coal companies in collaboration with the U. S. Bureau of Mines and the State mine inspection department, says D. S. Hanley, vice-president, Pacific Coast Coal Co., are among the most significant developments in Washington coal mining since 1911. "In this connection," he states, "we want to mention particularly the great progress that has been made in the efficiency of the electric cap lamp." This development, says D. R. Swem, manager of coal operations, Northwestern Improvement Co., "has led to greater comfort and higher efficiency, as well as greater safety."

Real progress has been made in recent years in reducing mine-accident hazards—particularly the major accidents, states Eugene McAuliffe, president, Union Pacific Coal Co. "Perhaps the U. S. Bureau of Mines, with its dogged persistency in insisting on ventilation, proper handling of gas, rock-dusting and the use of water, deserves the most credit for this betterment. If coal mines are ventilated, sprinkled and rock-dusted, we will have no major explosions such as the two which recently occurred in Great Britain.

"In this country, our losses from accidents come from the continual killing of one, two or three men. This represents a somewhat harder problem, but the fact remains that our inspection, both federal and State, is inadequate. In the case of federal inspection, the weakness lies in the fact that the average operator resents criticism by the very competent men employed by the Bureau of Mines. State inspectors are almost invariably the tools of politics, bounced into office and bounced out again each time the State government changes. These men should be technically trained, appointed on merit, brought under civil service and kept in office until disqualified by age, conduct or other justifiable cause."

Although mechanical loading now has the spotlight, the successive steps in the mechanization of mining proper also have had a major rôle in technical developments. Arduous undercutting with the pick, explains J. E. Butler, general manager, Stearns Coal & Lumber Co., in tracing this history, gave way to dangerous shooting on the solid. Then came the puncher, operated by compressed air; the machine, which was slow and cumbersome, caused excessive degradation. It was succeeded by the electrically operated chain breast machine, cutting a single kerf the width of the cutter bar about 4 or 5 ft. wide at a time. "Now we have the shortwall and the longwall machines, which undercut very rapidly and with a minimum of effort."

The increasing use and material improvement in cutting machines also impresses H. L. Richardson, vice-president, West Kentucky Coal Co., as one of the outstanding developments of the quarter century. Another is "the much wider use of anti-friction-bearings on mine cars. Improved construction of mine cars, particularly the cast-steel body and bodies of alloy materials, also should be included."

Looking to the future, Mr. Richardson joins the group that believe research developments in the more efficient utilization of coal probably will overshadow any technical advances in production. Mr. Hanley foresees more byproduct plants near large consuming centers, "where the coal will be coked and the gas, gasoline, oil, tar and other byproducts will be able to find a market. There is no doubt that in the years to come the situation in the United States will approach that already existing in Great Britain, Germany and other European nations." "With these developments," adds Moroni Heiner, president, Utah Fuel Co., "the consumer will receive greater heat value and there will be less raw coal used."

Less Waste in Mining

On the mining side, continues Mr. Heiner, there will be more mechanization, more complete recovery of the deposits worked and a greater use of substitutes for powder in breaking down the coal. Concentration of tonnage at large mines fully mechanized and operating 24 hours a day so as "to produce the greatest amount of coal with the lowest possible investment in equipment" will characterize developments in the next 25 years, in the opinion of B. W. Snodgrass, president, Moffat Coal Co. Coal, he believes, will be blasted out of the solid and reduced as nearly as possible to fines to be cleaned and shipped in pulverized form or burned at the mines to generate power.

The outstanding technical developments in the Southwestern field during the past quarter of a century, says W. C. Shank, president, Crowe Coal Co., have been in stripping and preparation. Adoption of stripping and improvement in preparation methods have saved the coal in-

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• With progressive ideas and the prevailing intense competition, we can reasonably expect further improvements in every branch of coal production, including underground operations, preparation at the face and marketing methods. Just as the more efficient byproduct ovens have replaced the beehive ovens, it is not unlikely that processes will be developed whereby the coal will be converted into power at the mouth of the mine or even inside of the mine. The situation may be summarized by saying that the coal industry has eliminated the word "impossible" from its vocabulary and what seemed to be an insurmountable problem yesterday will be solved today or tomorrow.—Carl Scholz.

dustry of that section from annihilation by oil and natural gas In the deep mines which have been able to survive the competitive struggle in that area, radical changes in methods have been necessary, states D. B. Withers, vice-president, McAlester Fuel Co. Longwall mining with conveyors has replaced the room-and-pillar system with solid shooting in many of the thin-seam districts of Arkansas and Oklahoma. Scow loading is used at some mines in the Paris and Poteau fields.

Extension of the use of electricity in mining and notable gains in safety impress Otto Herres, vice-president, United States Fuel Co., who is just rounding out 25 years of service in the Utah coal fields, as the outstanding developments in that State during the past quarter century. Back in 1911, "coal was mined with a pick, a shovel, a mule and a carbide or oil lamp. Today, in our larger mines we use cutting and loading machines, cable-reel or storage-battery locomotives and electric cap lamps. Roof conditions still require that a considerable percentage of coal be mined by hand for reasonably complete extraction in pillar drawing, but mechanization has been the outstanding development both underground and on the surface.

"Possibly the greatest developments in technical progress in the next quarter of a century will be in processing and improvements in the use of coal. I also would expect continued progress in underground mining practice through further and improved forms of mechanization, leading to concentration of mining to smaller areas of the mine, and probably a more extensive use of conveyors for haulage purposes."

Chain Principle Outstanding

"Invention of the chain principle in cutting is the most important improvement ever introduced into coal mining," according to Oscar Cartlidge. It made possible the coal-cutting machines of today; increased output; opened new markets; increased the number of mines; gave employment to more men in both mines and factories; reduced the price of coal to the consumer, and increased the wages of the miners.

Other outstanding advances include improved equipment to make mining safer. Preparation also has shown vast strides from the days when the loader picked out as much slate as he could—letting the rest go with the coal—to the separators, washers and air cleaners of today.

The greatest advances in the next quarter century are envisioned by Mr. Cartlidge along the lines of better equipment for mining the thinner seams and for greater recovery of coal from all seams. Though the thick and easy-to-mine coal is fast disappearing, it is becoming apparent that the thin coals in general are freer of impurities and of better grade than most of the thick seams.

When *Coal Age* made its bow, in 1911, J. J. Rutledge, chief mine engineer, Maryland Bureau of Mines, points out, the U. S. Bureau of Mines was just getting under way. The breast machine was beginning to pass out of the picture, giving place to the shortwall or the longwall mining machine. Col. James Elwood Jones was experimenting with a chain machine mounted on a railroad hand-car, the machine being equipped with a kingbolt which permitted the machine to swing in an arc of 180 deg. This was the predecessor of today's arc-wall machine.

About that time, thought began to be given to the underground conveyor introduced by C. R. Claghorn. "And what a far cry it is from this layout to the Harry Taylor mine in the anthracite region, where coal is taken from the face and delivered to the breaker by the use of conveyors, without transportation in mine cars." Although Joseph Leiter, after experiments with loading machines, decided to drop the matter and turn to some other method, his former plant is now entirely equipped with mechanical loading devices.

Progress in coal preparation is almost incredible when viewed in the light of 1911 practice, according to Mr. Rutledge. "Who would have thought that the refinements of precious-metal concentration would be applied to coal washing?" But he finds no less startling the complete mechanization of large mines in Illinois and Pennsylvania as well as the drilling of vertical shafts from 3 to 5 ft. in diameter from the surface with Calyx and other drills.

Heavier Steel Rails Used

Among the many improvements since the turn of the century, Carl Scholz notes the replacement of wood and light steel rails by 60-lb. rail and the appearance of steel cars carrying five tons or more in place of 1-ton mine cars. Concentrated mining methods, adopted to suit changes in power and equipment, he points out, have resulted in more economical and complete extraction, as compared with the old-type two-entry system with pillars and rooms. The importance of the chemist in this parade has steadily grown, since every constituent of the coal is now studied by the buyer.

★ ★

• Mechanization unquestionably has been the chief development in underground mining in the last 25 years—particularly if all its phases are taken into account. Coal-cutting machines have been improved to such an extent in the last five years that they hardly would be recognized by those not in touch with mining during the period. Mechanical loading had been developed to meet practically all conditions of underground work, either on flat or pitching seams.

• In line with improved machinery is the important technical development of explosive-proofing of equipment for use in gassy mines. Technical studies have shown the advantage and protection afforded by the introduction of rock-dusting and permissible explosives in dry and dusty mines.

• Considerable progress has been made in the technical development of coal preparation and cleaning. The perfect type of cleaning plant not only produces a much superior product but it likewise effects a saving of coal that in the past was wasted or lost.—D. R. Swem, Manager of Coal Operations, Northwestern Improvement Co., Seattle, Wash.

MECHANIZATION, improved preparation methods, electrification and the increase in the size of the pumping units installed have been the outstanding technical developments in the hard-coal industry during the past quarter of a century, in the opinion of operators intimately acquainted with the history of anthracite mining. Emphasis also is placed upon the fact that the mines now work much thinner seams. On the economic side, changing market demands, with an increasing shipment of the smaller sizes, and the development of equipment to burn those sizes in competition with bituminous coal, oil and gas are rated significant.

Future developments along the economic front will be influenced by these changes. Heating results and consumer convenience will be the watchwords in merchandising. Possibly a reduction in the number of sizes prepared will come. Deeper mining will introduce new problems in power generation and distribution and more attention will be paid to the possibilities of improving the power factor. And the question of bootleg coal, which has assumed such menacing proportions in the last few years, must still be faced.

"The most striking technical development since 1911," declares an executive of one of the larger companies, "has been the introduction and rapid application of the loading machine. Between 1918 and 1928, the anthracite region was about the only mining field where such equipment was used to any great extent. At the start, the work was done almost exclusively with scraper loaders but, beginning a little before 1928, shaker loaders were tried out and the use of that type of equipment has been sharply expanded.

"Anthracite leads the country in the proportion of its output that is mechanically loaded. Mechanization progress will continue. It has been forced upon the industry by the high wages which the anthracite region has paid for several years and is committed to pay for a further period. Human labor in the raw cannot be used to handle anthracite at a cost which will enable it to be marketed in competition with other fuels. Machinery, therefore, is necessary to bring these costs down to a basis that at least approaches a competitive level."

Purer Product Shipped

The change from dry to wet preparation methods has made it possible to ship a purer product. Coal seams which could not be worked because they were contaminated with refuse that could not be eliminated under the older cleaning systems now can be mined. This has greatly increased the quantity of coal which can be sent to market. "Subsidiary to this change, there has been a swing from the old-type jig to the Chance cone, Rheolaveur launder, Menzies jig and other newer types of cleaning devices. These all have had a profound influence on the quality of the product and have tended to constantly improve it."

Single pumping units of 5,000-, 6,000- and 8,000-g.p.m. capacity now are fairly common. They have been made necessary by the great increase in the amount of underground water to be handled—particularly in the Northern field—due to the continued disruption of the surface by pillar removal and consequent increased inflow of surface water. Significant in this connection, states this executive, "is the creation of extremely large sumps and the placing of pumps below the maximum level of the sump, with the pumproom protected from inundation by walls, so that the sumps themselves constitute enormously greater reservoirs than ever were contemplated twenty years ago.

HEAT—NOT COAL

● The industry must stop selling anthracite as such. This means that it must sell a type of upstairs heating results meeting every consumer desire and purse-string. Directly or indirectly we must further the application of improved equipment and dealers' services with which to obtain that result. Not only domestic stokers, but heat controls, hot-water heaters, efficient boilers and furnaces, insulating of kitchen ranges, air-conditioning and food-refrigerating units should be covered in the equipment program. . . . Research looking forward to economical operation; improved combustion, satisfying the desires of the public for "heat happiness," will, in my opinion, bring back to anthracite the position it formerly enjoyed as the premier domestic fuel.—Thomas Dickson, Dickson & Eddy.

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"The effect of taking mine water from the center of a huge pool, rather than from the turgid edges of the pool, is marked and is just beginning to be appreciated. During the next few years, the realization of the economies to be effected by this type of pumping will be widespread."

Twenty-five years ago, says J. T. Jennings, electrical engineer, Philadelphia & Reading Coal & Iron Co., the anthracite field was dotted with small electric generating stations—generally with low steam pressure and low-temperature non-condensing slow-speed engine-driven generators supplying low-voltage distribution for colliery operation. Application of electric power to mining was limited to electric haulage, small pumping and hoisting and some stationary motor drives.

"Today we find electric power rapidly superseding steam. With few exceptions, steam pumps have been replaced by automatic motor-driven centrifugal pumps. Electric hoists are being installed on all new shafts and slopes, and many steam-operated hoists are being changed over to electric drive. Coal breakers, ventilating fans, compressors are all electrical. Mechanical mining, not known in 1911, also is a heavy consumer of electric power.

"This great change was made possible by the development and application of motors and controls to meet the severe mining conditions. The constantly rising curve of demand for electric energy over the years has changed the trend of power generation. This trend has been characterized by a continued tendency toward centralization of power-generating equipment. In point of efficiency there is no comparison between the 1911 colliery plant and the modern turbo-generators operating at high pressure, high temperature heat cycles.

What of the future? "As underground mining goes deeper," states Mr. Jennings, "the power loads will follow. Feeder cables of higher voltages for transmission will be required both to reduce the weight of the cables and the power losses. To guard against underground fires from transformer troubles, transformers with non-inflammable and non-explosive properties will come into use. Due to its inherent advantages, the mercury-arc rectifier doubtless will displace rotary conversion equipment for d.c. supply. Much study will be given to power-factor correction; every consumer of electric power will be specifically rewarded if he improves his power factor."

Rolling back the scroll still farther, Eli T. Conner, who has been closely associated with the industry for more than fifty years, explains that, in the 1882-1892 decade, collieries were depending for power on cylinder boilers carrying about 80 to 90 lb. pressure. Steam was piped for long distances—sometimes as much as 4,000 ft. Non-condensing engines and pumps were standard. It was common practice to exhaust from pumps and engines into the sump, causing steam and moisture. Underground transportation was mostly by mules—well trained and well handled. Up to the close of the century it was generally considered unprofitable to exploit beds less than 5 ft. thick because of the necessity of brushing the roof or floor.

Good-Bye to Slate Pickers

"While jigs for separating impurities from coal had been introduced in the Southern and Eastern Middle districts in the late '70s and early '80s, until about 1900 it was the general practice in the Northern field to use dry preparation methods. This system resulted in excessive losses to the refuse bank. Newer systems introduced during the last fifteen years have made tremendous improvement in preparation. With mechanical cleaning, employment of a small army of boys as slate pickers no longer is necessary.

"On the mining side, the most outstanding developments during the last 25 years have been the introduction of undercutting machines and the transportation of the product across the face, either in chamber or longwall, by mechanical devices,

such as shaker chutes and conveyors and the use of steel jacks. This has resulted in substantial economies both in concentration of activities and in exceptional conservation. Beds as thin as 18 in. are being commercially recovered: this would not have been possible under the old practice of brushing roof or floor. These changes are largely confined to the comparatively flat measures of the Northern field."

Mechanization of loading and transportation devices is placed at the top of the list of major developments of the past quarter century by C. R. Seem, electrical engineer, Glen Alden Coal Co. Reduction in costs is vital to the future of the industry and mechanization seems to offer the greatest possibilities in that direction. Fewer sizes and the narrowing, or elimination, of the price differentials between buckwheat and the larger coals are foreseen by more than one contributor to this symposium. Such a change, it is agreed, would mean an increasing proportion of the total output in junior sizes.

From the production standpoint, fewer sizes, it is pointed out, would mean a reduction in the cost of mining at the face, a reduction in haulage costs and a drastic cut in the cost of preparation. On the marketing side, recognition must be given to the fact that the definition of what constitutes a "small" size has been changing. Back in 1911, No. 1 buckwheat was in that category; later that distinction was held in turn by rice and barley and now some would limit the application of the definition to still smaller coal. In the future, therefore, it is considered not unlikely that No. 1 buckwheat and all sizes larger will sell at a more nearly uniform price than in the past.

ECONOMIC STATUS OF COAL INDUSTRY

(*Concluded from page 396*)

price competition between the participating mines. This system, which has been approved by the Supreme Court as not inconsistent with the prohibitions of the Sherman Act, has yet to be thoroughly tested, because, while the Supreme Court decision was handed down early in 1933, the advent of NRA temporarily curtailed the full functioning of the district-sales-agency plan.

In summarizing the present economic status of the bituminous division of the coal-mining industry, therefore, it seems clear that the readjustment period upon which it is entering is one of recovery. Increasing mechanization is reducing costs, so that the competitive position of the industry is steadily improving. The vicissitudes of the last decade have given the industry as a whole a broader conception of its economic problems and a keener appreciation of the necessity of finding a sane solution. The feast-or-famine philosophy is on the way out.

For the moment, the situation in the anthracite side of the industry is less fortunate than that of the bituminous branch. Although bituminous coal production passed it in point of annual tonnage in the '70s, hard-coal production continued to show a fairly steady and consistent growth until 1915, when production was 88,995,000 tons. Wartime demands raised output to nearly 100,000,000 tons in 1917 and 1918. This increase, as subsequent developments proved, however, was not the blessing it then seemed. Under Fuel Administration regulations, anthracite was zoned out of many markets and distribution was largely confined to Eastern States. As a result, competitive fuels became more strongly intrenched in outlying markets. Prolonged strikes in later years, particularly 1922 and 1925-1926, further increased the hold of these fuels not only in outlying markets but also in the Middle Atlantic and New England States.

Changes Hit Production

The effects of these changes are plainly evident in the production records. Anthracite output, which topped 99,611,000 tons in 1918, declined steadily after 1926, dropping to 49,541,000 tons in 1932—the lowest in 30 years. Production crawled up to 57,163,000 tons the following year, but slid off to 51,003,000 tons in 1935. To add to the woes of the established producers, the depression also started the development of small, illegitimate mines—"bootleg" operations—extracting coal without the consent of the owners of the lands worked. Last year, it is estimated, these bootleg operations sold approximately 4,000,000 tons of stolen coal. This estimated tonnage is not included in the production figure given earlier in this paragraph.

First steps to combat the competitive inroads of other fuels were taken several years ago when the industry as a group organized Anthracite Service to help both operators and retail distributors in the analysis of combustion engineering problems. Still later the Anthracite Institute Laboratory was created at Primos, Pa. This laboratory (see p. 436) has not only tested combustion equipment and given its seal of approval to devices which met its requirements but also has done considerable research on competitive fuel problems. A number of individual operating companies, both large and small, also have labored long to improve merchandising.

Because anthracite is now primarily a domestic fuel, the possibilities of automatic coal burning for the home have been given increasing attention. A few companies have taken over the development and sale of stokers and other heating equipment and accessories. In addition, the Anthracite Institute Laboratory has been encouraging the development and perfection of equipment which will increase the cellar prestige of hard coal. Although fought at the outset by some producers and many retailers as a menace to the prosperity of the industry, most hard-coal men and bituminous interests, too, are now convinced that the stoker is coal's strongest ally in the fight to hold the domestic market against oil and gas and are actively cooperating in spreading the stoker story. The rapid increase in the volume of stoker sales has been one of the brightest spots in the coal picture the last two years.

The most recent step in the movement to regain lost markets was the organization this year of Anthracite Industries, Inc. Through this agency the industry plans a mass promotional campaign to carry the story of the advantages of hard coal and modern heating equipment direct to the consumer. Because competitive fuels have become so strongly intrenched in the anthracite markets, hard-coal recovery promises to be a long and difficult progress. In the light of the developments recited and of the united front which has been created in the industry, the long-range economic outlook for anthracite appears brighter than it has been in several years.

WORD FROM THE FIELD

State Authorities Assailed On Bootleg Mining

Pennsylvania authorities were scathingly censured for permitting what was termed "polluted commerce" in a presentment on Sept. 16 by the New York grand jury that had been investigating bootleg coal traffic from the anthracite fields to New York City. The report, which was filed with General Sessions Judge Cornelius F. Collins, besought officials of the Keystone State to protect legitimate New York business from "competition with organized thieves." The jury requested that Governor Lehman memorialize Governor Earle of Pennsylvania on the subject, and recommended that New York City and State legislative bodies enact laws to remedy the situation.

After asserting that Governor Earle and other Pennsylvania officials, although approached repeatedly by producers, had taken no steps to remedy illicit traffic in anthracite, the grand jury also submitted these conclusions:

"That ordinary comity between States imposes an obligation upon the Commonwealth of Pennsylvania to stop this condition of anarchy which results in a flow of polluted commerce into this State and thus imposes upon our taxpayers the heavy burden of enforcing the law against contraband commerce.

"That every consideration, practical and moral, calls for prompt and effective action by the Commonwealth of Pennsylvania to stop this evil. The city of New York should not be put to added expense to rectify wrongs which originate from the neglect of an adjoining State."

Hearing of evidence by the grand jury on bootleg coal traffic began Aug. 18, and its early sessions resulted in the indictment on Aug. 27 of two coal dealers on a charge of criminally receiving coal stolen in the anthracite fields (*Coal Age*, September, p. 381). Frank L. Nowasatka and William Slutsky, the indicted dealers, were released in $2,500 bail each, pending trial. In its consideration of the question the jury heard 51 witnesses. The inquiry was conducted by Assistant District Attorney John C. McDermott.

Eight more trucks, each loaded with ten tons of anthracite alleged to have been stolen from the hard-coal region, were seized on Sept. 4 by New York detectives as they emerged from the Holland Tunnel and downtown ferries along the Hudson River. After questioning by Mr. McDermott ten of the drivers and helpers were freed with instructions to return when required, prepared to be arraigned and furnish bail on charges of bringing stolen coal into the State.

Five days later, threats of reprisals by cities in the anthracite region on New York trucking concerns, because of the seizure in the latter city of trucks containing coal

alleged to have been stolen from the mines, reached Mr. McDermott. The prosecutor said he had been informed that Earl Humphreys, president of the Independent Anthracite Miners and Truckers Association of Reading, announced that the municipal authorities had agreed to pass ordinances requiring New York truckmen to pay heavy assessments for transporting merchandise through their territories.

Keeping Step with Coal Demand

Bituminous Production

Week Ended	1936 (1,000 Tons)	1935* (1,000 Tons)
Aug. 1	7,402	5,388
Aug. 8	7,592	4,922
Aug. 15	7,740	5,569
Aug. 22	7,633	6,279
Aug. 29	7,996	7,456
Sept. 5	8,214	6,948
Sept. 12	7,790	8,388
Total to Sept. 12	279,604	251,443†
Month of July	32,054	22,339
Month of August	32,818	26,164

Anthracite Production

Aug. 1	1,100	839
Aug. 8	550	433
Aug. 15	591	446
Aug. 22	661	413
Aug. 29	1,084	1,088
Sept. 5	728	531
Sept. 12	718	794
Total to Sept. 12	35,346	35,951
Month of July	4,127	3,536
Month of August	3,235	2,591

* Outputs in these columns are for the weeks corresponding to those in 1936, although these weeks do not necessarily end on the same dates.
† Adjusted to make comparable number of working days in the two years.

Bituminous Coal Stocks

(Thousands of Net Tons)

	Aug. 1 1936	July 1 1936	Aug. 1 1935
Electric power utilities	5,887	5,548	6,635
Byproduct ovens	5,302	4,565	6,608
Steel and rolling mills	917	874	1,409
Railroads (Class 1)	4,324	4,351	8,518
Other industrials*	7,781	7,615	10,102
Total	24,211	22,953	33,272

Bituminous Coal Consumption

(Thousands of Net Tons)

	July 1936	June 1936	July 1935
Electric power utilities	3,597	3,153	2,911
Byproduct ovens	5,332	5,325	3,996
Steel and rolling mills	1,010	1,045	901
Railroads (Class 1)	6,500	6,255	5,766
Other industrials*	8,543	8,270	6,725
Total	24,982	24,048	19,520

* Includes beehive ovens, coal-gas retorts and cement mills.

Coal Processing in Spotlight At Chemists' Meeting

Hydrogenation, carbonization, mechanism of solid-fuel combustion, the constitution of coal and briquetting were the topics discussed at the meeting of the division of gas and fuel chemistry, American Chemical Society, held Sept. 7-11 at the William Penn Hotel, Pittsburgh, Pa. Dr. O. O. Malleis, of Appalachian Coals, Inc., Cincinnati, chairman, presided over the sessions.

Dr. M. Pier, research director, I. G. Farbenindustrie, A. G., Germany, explained how, by use of destructive catalytic hydrogenation, fuels like coal, tar, petroleum and shale oil give high yields of products usually obtained from mineral oils. Practically the only byproduct is a certain quantity of gaseous hydrocarbons, which, however, may be utilized in the process by conversion to hydrogen. Catalytic hydrogenation makes possible the production from the same raw material of different final products such as fuel oil, lubricating oil, diesel oil, illuminating oil, or gasoline.

An apparatus and method for continuous hydrogenation tests on coal were described by T. E. Warren and R. E. Gilmore, fuel research laboratories, Canadian Department of Mines. In this method powdered coal is mixed with heavy oil and a small quantity of tin oxide, which aids the reaction, and the mixture is pumped into the reaction chamber, where it is heated to about 840 deg. F. and treated with hydrogen at a pressure of 3,000 lb. per square inch. The liquid product is an oil from which crude gasoline may be distilled.

The mechanism of coal hydrogenation has been studied at the Fuel Research Station of Great Britain especially for the light it sheds on coal constitution, according to a paper by F. S. Sinnatt, director; J. G. King and Angus MacFarlane. Special attention has been given to the hydrogenation and treatment of low-temperature tars, the authors reviewing the influences of pressure and temperature upon the hydrogenation and cracking of the aromatic constituents of low-temperature tars, especially with reference to naphthalene.

An experimental procedure for complete conversion into liquid or soluble products of all the banded constituents of bituminous coal other than fusain was outlined by C. C. Wright, M. M. Baldwin, C. C. Hsaio and A. W. Gauger, Pennsylvania State College. Experimental data presented showed that the degree of conversion obtainable by hydrogenation of organic material in the coal is limited only by the percentage of fusain present and by the conditions of the hydrogenation. Burnard S. Biggs and J. F. Weiler, Carnegie Institute of Technology, described the chemical constitution of bituminous coal

as revealed by its hydrogenation products. An investigation of the action of aqueous alkali on coal from the Pittsburgh seam was described by Leo Kasehagen, Carnegie Institute of Technology.

At the session devoted to consideration of carbonization of coal, L. D. Schmidt, J. L. Elder and J. D. Davis, U. S. Bureau of Mines, gave an account of the oxidation of coal at storage temperatures and the effect on its carbonizing properties. William B. Warren, Carnegie Institute of Technology, told of the effects of the rate of heating and of final maximum temperature in the carbonization of a series of coals of increasing rank. "Coke From Illinois Coals: Temperature Conditions in Sole Flue Ovens," was treated by Gilbert Thiessen, Illinois Geological Survey. Plasticity of coals—its measurement and relation to quality of coke produced was explained by R. E. Brewer and R. G. Atkinson, University of Minnesota.

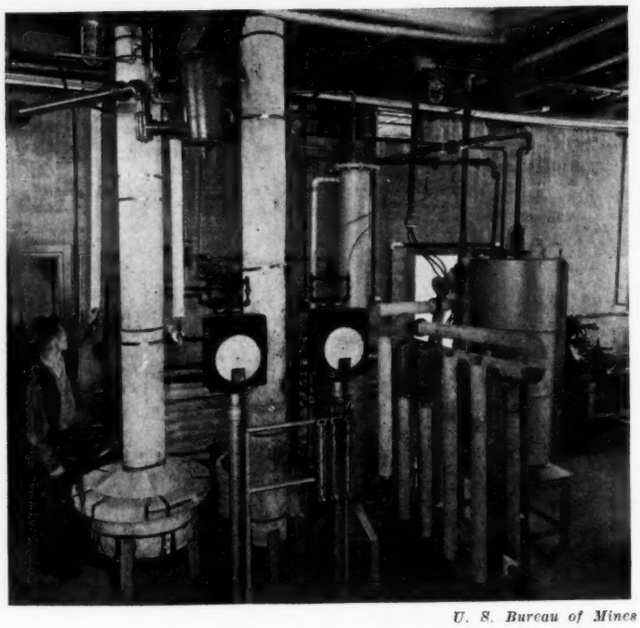
Reinhardt Thiessen and G. C. Sprunk, U. S. Bureau of Mines, presented a paper at the session on the constitution of coal which narrated the origin of the granular opaque matter in splint coals. Oxidation of a Pittsburgh seam bituminous coal and low-temperature coke by alkaline permanganate was related by Barnard Juettner, R. C. Smith and H. C. Howard, Carnegie Institute of Technology. Aromatization of cellulose by heat was described by R. C. Smith and H. C. Howard, Carnegie Institute of Technology.

A study of dust-laying practices on soft coals having emphasized the need of a more permanent treatment than is commonly used, H. R. Fife and P. W. Edeburn, Mellon Institute of Industrial Research, revealed the results of experiments with amorphous paraffin wax as a protective coating and dustproofing agent for solid fuels. Results obtained in determining the fusibility of coal ash by the A.S.T.M. standard gas-furnace method were discussed in a paper by J. J. Brennan, D. F. Mitchell, F. P. Tierney and W. C. Thompson. A new method for the quantitative determination of fusain was set forth by C. C. Hsaio, W. M. Fuchs and A. W. Gauger, Penn State College.

The briquetting of coal without a binder was described in papers by F. H. Fish, Virginia Polytechnic Institute, and C. A. Basore, Alabama Polytechnic Institute. Prof. Basore also told of a study of the properties and possible methods of utilizing Alabama lignites. In a paper on "The Oxidation of Anthracite," G. S. Scott and G. W. Jones, Pennsylvania State College, described a method and apparatus for obtaining the relative rates of liberation of carbon monoxide from carbonaceous substances during heating and for determining the ignition temperatures at the same time. A study of gas-film structure by micro-sampling in connection with the combustion rate of carbon was outlined by Almon S. Parker and H. C. Hottel, Massachusetts Institute of Technology.

Panther Creek Resumes

Panther Creek No. 2 mine of the Panther Creek Mines, Inc., at Springfield, Ill., which had been closed since April 15, was reopened on Aug. 31. Two hundred men are at work and vapor equipment for dedusting the coal has been installed.



U. S. Bureau of Mines

Experimental hydrogenation plant at the U. S. Bureau of Mines Experiment Station, Pittsburgh, Pa.

Will Urge Rigid Inspection Before Reopening Mines

Action to prohibit the reopening of abandoned mines without rigid State inspection is expected to be taken by the State mining department of Missouri as a result of two recent mishaps near Fulton and near Moberly which took a toll of six lives. State mine inspectors who aided in the recovery of the bodies of the victims of these disasters have announced that they will ask the next General Assembly to enact more stringent regulations for coal mines that are to be reopened.

Four brothers lost their lives, three in an attempt to rescue the fourth, on Sept. 1 in the Metz mine, near Fulton. The dead are Louis Metz, 32, owner of the mine; Ernest, 23; Fred. 21, and Harry, 19. Death was caused, according to Coroner I. W. Holman, by carbon-monoxide gas generated by a gasoline engine being used to pump water from the mine. Two weeks previous, two men were fatally overcome by fumes when the superstructure of a mine near Moberly caught fire.

Coal-Hydrogenation Plant Started at Pittsburgh

An experimental hydrogenation plant that will produce gasoline from coal is ready to start operations at the U. S. Bureau of Mines Experiment Station, Pittsburgh, Pa. The plant, which is designed to hydrogenate about 6 lb. of coal per hour, includes apparatus for the production of hydrogen from steam and natural gas, compressors for producing the desired hydrogen pressure, and alloy steel converters for conducting the reaction between coal and hydrogen. The chemical combination of a relatively small percentage of hydrogen with certain types of coal results in an oil similar to crude petroleum. This combination of coal and hydrogen is effected under moderately high pressures and at temperatures of about 850 deg. F.

The main objective of the Bureau of Mines in conducting the work to be done in the coal-hydrogenation laboratory, according to Dr. H. H. Storch, supervising physical chemist, in charge of the work, is to provide information concerning the characteristics of American coals for hydrogenation purposes. Such information is considered a desirable preparation for the time when the United States finds it necessary to provide additional sources of motor fuel and lubricating oils. The process for producing gasoline from coal has been developing rapidly in Germany during the last decade, the production capacity of the German coal-hydrogenation plants at present being close to 500,000 tons of gasoline per year. In England, operation of a large plant was started recently at Billingham.

Resents Commercial Activity Of Captive Producers

Aroused by the expanding activities of producers of captive bituminous tonnage in the commercial markets, the National Coal Association, in its bulletin of Sept. 12, hints at the advisability of reprisals with the query, "Should we manufacture our steel?" Specifically the producers' organ points out that the Goodyear Tire & Rubber Co., with a coal mine in Ohio, sells a substantial quantity of coal in the commercial market "in direct competition with those whose business is producing coal."

What is designated as a "startling development" is the completion of arrangements by the United States Steel Corporation, according to the operators' bulletin, to sell about 250,000 tons of prepared sizes from its mines in eastern Kentucky through a well-established coal company. At the same time, says the producers' organ, the steel company is buying an equal quantity of steam coal from other producers at from

75c. to $1 per ton less than it proposes to sell its larger sizes to consumers. By this arrangement, N.C.A. states, "it is easy to estimate that some $200,000 annually has been saved at the direct expense of the commercial coal producer."

Many millions of dollars in mining properties and equipment have been invested by the bituminous coal industry of the United States, the bulletin asserts, "in order to establish itself as the most efficient coal-mining industry in the world. The technique of production, preparation and marketing has reached a high point of perfection. The industry is able to meet the demands of the nation in a sound and businesslike way. The producer of bituminous coal does not believe in invading the ranks of other industries and producing or manufacturing an article or commodity simply because the coal industry happens to use a large quantity of that article or commodity.

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West Kentucky Raises Wages And Signs Union Pact

A strike for increased wages and union recognition which lasted more than a year in Muhlenberg and Ohio counties, western Kentucky, came to an end on Sept. 23, when the Western Kentucky Coal Operators' Association and officials of District 23, United Mine Workers, reached an agreement. The agreement provides for higher wages and a seven-hour day, effective until April 1 next. The new pact fixes wages of outside mine labor at $3.50 a day and inside labor at $4.50, an increase of 50c. Loaders will receive 49.11c. a ton, and machine helpers, 3.95 and 3.98c., compared to the old scale of 41.14, 3.45 and 3.48c., respectively. About 2,500 miners have been on strike.

Coal mining in Kentucky, both the eastern and western areas, had been plagued with labor unrest. A special grand jury was impaneled in the Bell County Circuit Court at Pineville on Sept. 15 and ordered by Judge James M. Gilbert to investigate charges of lawlessness at some of the mines.

Employees of the Fox Ridge Coal Co. were attacked and beaten when they attempted to clean up the company's mine preparatory to reopening. It was alleged that members of the United Mine Workers staged the demonstration to prevent the mine, which had been closed several weeks, reopening on a non-union basis. County Judge D. M. Bingham, on Sept. 12, dismissed charges against 60 pickets alleged to have banded together to commit a felony at the Fox Ridge mine. Judge Gilbert also directed the jury to investigate disorders reported at Four Mile, where it was alleged that strikers were preventing resumption of operations.

In western Kentucky, three men were indicted at Greenville on Sept. 15 in connection with the shooting of two miners on July 17 at the Rogers Brothers Coal Co. mine, Bevier. One of the victims died shortly after the shooting, but the other recovered. The Rogers mine, as well as several other large operations in Muhlenberg County, has been closed for more than a year because of a strike of union miners. The Hickory Coal Co. mine at Mannington also closed following an explosion in the tipple on the night of Sept. 14.

Coal Resources and Stabilization Scanned At Third World Power Conference

WITH about 3,000 delegates taking part, including more than 700 from foreign countries, the Third World Power Conference opened in Washington, D. C., on Sept. 7 and held sessions daily until Sept. 12. The high spot of the coal program, which occupied a conspicuous place in the conference, was the presentation on the first day of a paper on the organization of the production, processing and distribution of coal and coal products in the United States, prepared by J. P. Williams, Jr., president of the National Coal Association and of the Koppers Coal & Transportation Co.

Reserves of bituminous coal in this country are so great and so easily accessible, Mr. Williams pointed out, that the opening of new mines is comparatively inexpensive. With mine capacity greater than demand, the excessive competition has limited returns to both capital and labor engaged in the industry. Then, too, a declining market has been caused partly by the adoption of improved methods of preparing and utilizing coal and partly by the inroads of such other sources of energy as fuel oil, natural gas and hydro-generated electricity.

Besides the demoralization resulting from excess capacity—to say nothing of the depression beginning in 1929—Mr. Williams called attention to the problems created by irregularity in demand due to industrial developments and climatic changes. Since these changes are spasmodic, there is a constant fluctuation in demand and irregularity in operation, which contribute to high cost of mine operation and unsatisfactory earnings for mine employees.

The greatest handicap to the industry in meeting competition of rival fuels, according to Mr. Williams, has been the freight charge on coal, exceeding on the average, as it does, its mine price. Though a certain amount of relief from this burden has been found in shipping via inland waterways and by truck, the operators' representative still considers that reduced freight rates would be of material assistance in the efforts of operators to meet competition from other sources of energy.

The effort to reduce production cost by the adoption of labor-saving devices was noted, undercutting by machine and electric haulage being almost universal except in very small mines, according to Mr. Williams. He stressed the great development in the industry in the direction of mechanical loading underground, sharply stimulated by recent advances in wages and shortened hours.

Among the efforts at stabilization of the industry the operators' spokesman emphasized the endeavors of the producers themselves, through such organizations as Appalachian Coals, Inc. The only remaining survival of the government's two recent attempts at stabilization, he said, was to be found in a 30 per cent reduction in the hours of labor of mine employees and a proportionate increase in their wages per hour, the importance of this fact being emphasized when it is remembered that labor cost constitutes more than 60 per cent of the total cost of producing coal.

The industry is seeking a way out of its overdeveloped condition, it was shown, by carrying on research into the uses of coal and its byproducts with the hope of finding new uses capable of large expansion.

Sir Harold Hartley, director of research, London, Midland & Scottish Ry., declared that despite the enormously increased demands made upon coal in Great Britain, which lacks other fuel sources, these demands have been met by increased efficiency and economy of operation without greatly increasing the quantity of coal consumed in the tight little isle. He added that the greatest hope of the future lay in the fact that methods "less brutal" are being developed for the handling and carbonization of coal; in this connection he lauded the work of Dr. Lowry, of Carnegie Institute of Technology.

Hosford Urges Output Control

Speaking for the National Bituminous Coal Commission, Charles F. Hosford, chairman, stressed the need for more and better organized regulation of production. He contended that since the Supreme Court ruling overthrowing NIRA the coal industry in this country had suffered tremendously, and asserted that "federal regulation of production appears to be the only way of obtaining relief from conditions now oppressing the industry," which, he added, bid fair to become worse with the passing of time.

W. A. Lee, secretary of the Mining Association of Great Britain, pointed out that the interests of the consumer and the operator are virtually the same, these being to maintain economic and industrial peace and reasonably priced coal, since high-priced coal hurts both the user and producer by forcing an artificial limitation on production. He urged the increasing importance of what he termed "organized control," laying stress on the fact that "mere price control is worthless, since evasion is so easy."

The difficulty of maintaining any real control of prices was stressed by Howard N. Eavenson, of Eavenson & Alford, who

Coming Meetings

- West Virginia Coal Mining Institute: annual meeting, Oct. 9 and 10, Logan, W. Va.
- Coal Producers' Association of Illinois: annual meeting, Oct. 13, Springfield, Ill.
- American Institute of Mining and Metallurgical Engineers, Coal Division: annual meeting, Oct. 21-22, Pittsburgh, Pa.
- Illinois Mining Institute: forty-fourth annual meeting, Oct. 23, Hotel Abraham Lincoln, Springfield, Ill.
- Indiana Coal Operators' Association: annual meeting, Nov. 17, Terre Haute, Ind.

also called attention to the vast quantities of the product and the ease with which control could be circumvented.

The predicament of France, which forces her to import coal because she cannot produce sufficient to meet her own demands, was explained by Armand Galliot, Director of Mines. He said, however, that efforts are being made to maintain a definite balance between production and consumption.

The session on conservation of coal resources, presided over by George H. Ashley, State Geologist of Pennsylvania, as chairman, which was held Sept. 9, elicited deep interest. The chairman remarked that the United States is far behind many other countries in methods of coal conservation. The tremendous overcapacity of the United States, he conceded, is not conducive to the establishment of any broad conservation attempt, despite the threat that some of our better grades of coal will be exhausted in less than a century. However, he added, conditions are now forcing this country to pay more attention to the problems involved, and consequently it is watching with keen interest the steps being taken in other countries.

Sir Harold Hartley said that Great Britain has coal reserves sufficient for 500-700 years, but said that this did not mean that there is not pressing need to get the uttermost out of the coal obtained from the British mines. He pointed out, however, that unless there is exact information concerning the different types of coal, any attempts at conservation are likely to go astray and prove valueless. He defined conservation as "wise spending" and lauded the work of the British coal survey, which, he declared, has given an entirely new view of the nation's coal resources and has, among other things, shown a clear path toward the proper methods in the chemical treatment of coals.

Stressing the effects of increased efficiency on the quantity of coal consumed, Dr. F. S. Sinnatt, British director of fuel research, said that the British census of production showed that 11 per cent less coal was required in 1930 than in 1924, though the energy output increased 9 per cent. He estimated that 20,000,000 more tons of coal would have been required in 1930 if the methods had remained unimproved. He emphasized the need of applying conservation to the more valuable and least abundant coal first, which he admitted requires a detailed knowledge of the country's coal seams so as to determine the quantity of each type. Knowledge of the uses of coal as a source of new products, he contended, is still in its infancy, and added that if conservation is to be worth while it must be in relation to the qualities of the coal available in any given country.

Susquehanna Colliery Resumes

No. 6 colliery of the Susquehanna Collieries Co., at Glen Lyon, Pa., resumed operations Sept. 1 with 700 men at work, after being closed since the middle of May for repairs and improvements. The mine regularly employs 1,200 men, but, for a while at least, two of the openings, No. 1 drift and No. 7 shaft, will not be worked.

HARTNEADY PLANS SAFETY DRIVE IN HARD-COAL FIELD

Plans for a safety drive in the anthracite mines near Hazleton, Pa., were revealed by Michael J. Hartneady, State Secretary of Mines, in an address on Sept. 7 when the Y.M.C.A. school for mining study opened. Mr. Hartneady suggested that a safety council be formed at each colliery, the members of which would be expected to report various conditions prejudicial to safety. An award of trophies to winners of contests on a monthly basis also was proposed by the Secretary.

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Passage of New Guffey Bill Considered Likely

Passage of a revised Guffey bill at the next session of Congress is taken for granted. Active support for the original measure was not confined to Democratic members. Some of the bill's strongest supporters in committee were Republicans. Apparently no way has been found around the Supreme Court's ruling against the labor provisions of the original bill. The substitute measure which failed of passage at the last session authorizes price fixing without providing for the control of production. As this is recognized as a serious weakness, an effort will be made to include allocation of tonnage in the new bill. The Bituminous Coal Commission is making an elaborate report on the subject. Its recommendations may be the basis of tonnage allocation provisions of the new measure.

There is a strong feeling in Congress that coal mining cannot be conducted satisfactorily without federal control. As long as anyone can open a coal mine at will it is recognized that demoralizing and wasteful overproduction will prevent stabilization of the industry. At the same time Congress hesitates to attempt legislation that would control the opening of new mines, even if a constitutional way of doing it could be found. To give a politically minded commission in Washington authority to withhold a certificate of convenience and necessity for a new coal mine raises doubts in the minds of even the most liberal among the legislators. It would be easy for a time, as the country could get along for several years without any new mines, but when new production would be needed, controversy would arise as to the distribution of permits. Requirements might be met best by issuing permits in West Virginia, but Pennsylvania would protest.

First-Aid Meets Held

Eight teams tied for first place in the first-aid meet of the New River and Winding Gulf Mining Institute, held Sept. 19 at Beckley, W. Va. It was necessary to have three teams work on a second run-off problem after five had been eliminated with an extra problem. The Helen team of the Koppers Coal & Transportation Co. was the ultimate winner, nosing out the Mabscott and Skelton teams of the New River Co. The other five teams, eliminated in the first extra test, were: Eccles, Crab Orchard Improvement Co.; Price Hill, Price Hill Colliery Co.; Long Branch, Koppers Coal & Transportation Co.; Raleigh, Raleigh Coal & Coke Co.; Winding Gulf, Winding Gulf Collieries Co.

The Coal River Mining Institute held its eleventh annual safety meet on Sept. 5 at Madison, W. V. In addition to the contests, there were addresses by A. C. Griffith, Mayor of Madison; H. L. Copher, president of the institute; N. P. Rhinehart, chief of the West Virginia Department of Mines, and A. G. Matthews, State Compensation Commissioner.

The first-aid contest for white men's teams was won by the Nellis Coal Corporation No. 6 team, from Nellis, W. Va., which received a silver trophy donated by the National Coal Association. The Youghiogheny & Ohio Coal Co. No. 8 team, from Van, W. Va., was second, and the Boone County Coal Corporation No. 20 team from Sharples, W. Va., was third. Teams in the colored division finished as follows: American Eagle Colliery Co., Ameagle, W. Va., first; Boone County Coal Corporation, Sharples, second. P. D. McMurrer, director of safety, West Virginia Department of Mines, was director of the meet, assisted by R. L. Jenkins and H. P. Farley, district mine inspectors.

Smokeless Coal Exposition Held at Mt. Hope

Numerous manufacturers of national repute as well as local supply and sales companies took part in the Smokeless Coal Industrial Exposition, held Aug. 27-29 at Mt. Hope, W. Va., under the auspices of the New River and Winding Gulf Electrical and Mechanical Institute. Exhibits were shown in the Y.M.C.A. building and the armory, the exhibitors including the following:

Air Reduction Sales Corporation, Allen-Bradley Co., Allis-Chalmers Mfg. Co., American Car & Foundry Co., American Foundry Co., American Oil Co., American Steel & Wire Co., Appalachian Electric Power Co., Ames-Baldwin-Wyoming Co., Automatic Coal Burner Co., Automatic Reclosing Circuit Breaker Co., Banks-Miller Supply Co., Beckley Hardware & Supply Co., Beckley Machine & Electric Co., Brown-Fayro Co., Bryant Electric Co., Central Shoe Co., Charleston Electrical Supply Co., Chicago Pneumatic Tool Co., Cincinnati Mining Machinery Co., Coal Age, Cole & May, Cooper Bessemer Co., Crane Co., Cutler-Hammer, Inc., Deming Pump Co., Duncan Foundry & Machine Co., Duquesne Mine Supply Co., Electric Railway & Equipment Co., Electric Railway & Improvement Co.

Fairbanks, Morse & Co., Fiske Bros. Refining Co., General Cables Corporation, General Electric Co., Graton & Knight Co., Great Western Fuse Co., Gulf Oil Corporation, Hungerford & Terry, Ingersoll-Rand Co., I-T-E Circuit Breaker Co., Justrite Mfg. Co., Mabscott Machine & Electric Co., Mine Safety Appliances Co., Monarch Fuse Co., Mosebach Electric & Supply Co., National Electric Coil Co., Ohio Brass Co., Patterson-Kelly Co., Pomona Pump Co., Portable Lamp & Equipment Co., Post Glover Electric Co., Princeton Foundry & Supply Co., Frank Prox Co., Pure Oil Co., Raleigh Hardware Co., Rockbestos Cable Co., John A. Roebling's Sons Co., Joseph T. Ryerson & Sons, Inc.

Safety First Supply Co., Safety Mining Co., Simplex Wire & Cable Co., SKF Ball Bearing Co., Stallard Studio, Standard Oil Co., Stephens-Adamson Mfg. Co., Sterling Pump Co., Timken Roller Bearing Co., Tool Steel Gear & Pinion Co., Troco Lubricating Co., U. S. Bureau of Mines, Universal Lubricating Co., Universal Pipe Co., Viking Mfg. Co., Westinghouse Electric & Mfg. Co., West Virginia Department of Mines, West Virginia Steel Corporation, West Virginia University Extension Department.

Varied Program Arranged for Coal Division Meeting

A wide variety of topics will be considered at the two-day meeting of the Coal Division of the A.I.M.E. to be held Oct. 21-22 at Pittsburgh, Pa. There will be a choice of three inspection trips in addition to the following papers:

"A Contribution to the Understanding of the Combustion of Bituminous Coal on the Small Underfeed Stoker," R. A. Sherman and E. R. Kaiser, Battelle Memorial Institute; "Pillar Extraction in Heavy Pitching Coal Seams," R. W. Smith, Acting State Geologist, Atlanta, Ga.; "Application of Duckbill Loaders in Anthracite Mines," F. H. Wagner, vice-president, Lehigh Valley Coal Co.; "Production and Reserves of the Pittsburgh Coal Bed," G. H. Ashley, State Geologist, Harrisburg, Pa.; "Some Factors Affecting Combustion in Fuel Beds," Martin A. Mayers, Carnegie Institute of Technology; "Shaking-Conveyor Mining in Pitching Seams in the Southern Wyoming Coal Field," F. V. Hicks, Union Pacific Coal Co.; "Benefits From Low-Temperature Coke," Hugh Archbald, consulting engineer; "Studies on Fusain," W. M. Fuchs, A. W. Gauger, C. C. Hsaio and C. C. Wright, Pennsylvania State College; "Cleaning Bituminous Coal While Cutting," William Reynolds, Jr., Goodman Mfg. Co.; "Propeller-Type Fans for Mine Ventilation," T. H. Troller; "Furnace Design and Prevention of Clinker," Allen J. Johnson, director, Anthracite Institute Laboratory; "Method of Determining Smoke Indices of Bituminous Coals," R. J. Piersol, Carnegie Institute of Technology; "Correlation of Coal Beds of Illinois and Indiana," H. R. Wanless and J. M. Weller; "Interrelation of Coal Preparation and Sales and Production Departments of a Coal Company," J. G. Bently, Sahara Coal Co.; "Planning a Definite Safety Program for a Mine, a Group of Mines or a Mining Region," M. J. Ankeny; "Problems of Iron Sulphide in Coal," S. P. Burke, West Virginia University.

Rochester to Get Natural Gas

The New York Public Service Commission granted on Sept. 24 the petition of the Cabot Gas Corporation for authority to construct a 92-mile transmission line to bring natural gas from Pennsylvania and southern New York to the city of Rochester. The line, with spur connections, will cost about $1,750,000. The proposed 14-in. pipe line will benefit industrial customers primarily, but it also is planned to sell gas to domestic users in about half the townships through which the line will pass.

Plan British Coal Convention

The Second National Coal Convention, being organized by the British Coal Utilization Council, will be held at Grosvenor House, London, on Oct. 29 and 30. The meeting will be divided into four sessions and all papers will be circulated among members in advance, time being provided for discussion after the presentation of each. The program includes the following papers:

"From Seam to Cellar—the Cost of Distribution," Errington Brewis, president, Coal Merchants' Federation of Great Britain; "What the Collieries Are Doing to Meet the Requirements of the Consumer," C. Augustus Carlow, president-elect, Institution of Mining Engineers; "What the Distributors Are Doing to Meet the Requirements of the Consumer," J. R. Hopper, past chairman, Rail-borne Factors and Wholesale Merchants' Association; "Developments in the Use of Solid Smokeless Fuels," John Roberts; "The Use of Solid Fuel in Relation to General Agricultural and Horticultural Problems," W. F. Bewley, director, experimental and research station, Cheshunt; "Sales Training and the Force That Should Be Behind It," Harold Whitehead; "The Trend of Design in Modern Coal-Burning Appliances," J. G. Bennett.

Differential Parley Adjourns

The North-South wage differential commission set up under the Appalachian agreement met Sept. 1 at the Shoreham Hotel, Washington, D. C., to consider the general subject of differentials. Following meetings of the operators of the various districts and general meetings of operators, the meeting of the full differential commission of 56 was held. The chairman, D. C. Kennedy, executive secretary, Kanawha Coal Operators' Association, reported to the commission that some of the districts had withdrawn their complaints without prejudice and others requested adjournment of the conference subject to the call of the chairman. The latter suggestion was adopted unanimously.

Not Keystone

In the article on transportation practices at the Clyde mines of W. J. Rainey, Inc., September *Coal Age*, p. 362, it was erroneously reported that the creosoted ties used in track construction were supplied by the Keystone Wood Preserving Corporation. Actually, these ties were purchased from the Adelaide (Pa.) plant of the Century Wood Preserving Corporation, now a part of the Wood Preserving Corporation, of Pittsburgh, which has furnished all the creosoted mine ties used by the Rainey organization.

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MECHANICAL STOKER SALES SOAR

SALES of mechanical stokers in July last totaled 6,288, of which 5,488 were small residential-size units, according to statistics furnished the U. S. Bureau of the Census by 108 manufacturers. This compares with sales of 4,898 units in the preceding month and 3,357 in July, 1935. Figures for the first seven months of this year show that 26,051 units of all types and sizes were sold, compared with 13,590 in the corresponding period a year ago. Sales by classes in the first seven months of this year were as follows: residential (under 100 lb. of coal per hour), 22,944; apartment-house and small commercial heating jobs (100 to 200 lb. per hour), 1,252; general heating and small high-pressure steam plants (200 to 300 lb. per hour), 523; large commercial and high-pressure steam plants (over 300 lb. per hour), 1,332.

Personal Notes

A. W. CAREY, traffic manager, Tennessee Coal, Iron & Railroad Co., was elected to the board of governors of the Southern Traffic League at its annual meeting in Atlanta, Ga.

SAMUEL DAVIS has been appointed mine foreman at the Black Betsy mine of the Fortune Coal Co., in Clay County, West Virginia.

GENERAL PRICE P. DISQUE has resigned as president of Pattison & Bowns, Inc., New York anthracite distributor, effective Sept. 1. General Disque became head of the firm on Oct. 2, 1933, succeeding Gardner Pattison. For two years previous to that time he had been executive director of the Anthracite Institute. HARRY T. PETERS, long connected with Williams & Peters, has been made chairman of the board, and WILLIAM GOHL has returned to the organization, after a short absence, as vice-president in charge of sales.

E. G. ERDMAN, formerly mining engineer at Colliery No. 7, Susquehanna Collieries Co., Nanticoke, Pa., has been appointed mining engineer for all the company's operations, vice W. B. Geise.

W. B. GEISE, mining engineer, Susquehanna Collieries Co., Nanticoke, Pa., has been appointed purchasing agent, succeeding C. K. Gloman, retired.

C. K. GLOMAN, purchasing agent, Susquehanna Collieries Co., Nanticoke, Pa., has retired from that position because of ill health. He will retain his connection with the company, however, with which he has been associated for 50 years.

E. R. JOBES has been named superintendent of the Maiden mine of the Kellys Creek Colliery Co., in Monongalia County, West Virginia.

OSBORN MONNETT, of the Commercial Testing & Engineering Co., has been named by Mayor B. F. Dickman of St. Louis, Mo., to investigate the status of smoke abatement progress in that city. Hearings are to be held shortly with interests concerned, after which a report will be submitted to the Mayor together with recommendations governing future activity in connection with the work.

W. S. MOORE has been made general night foreman of the Rich Run mine of the Elk River Coal & Lumber Co., in Clay County, West Virginia.

PATRICK F. NAIRN, a Cambria County (Pa.) mine inspector, was appointed by Governor Earle on Sept. 28 as Deputy Secretary of Mines of Pennsylvania, bituminous division.

EDWARD S. O'CONNOR, heretofore in charge of iron mining for the Columbia Steel Co., has also been made general superintendent of the company's coal properties at Columbia, Utah, in conformity with a decision to combine the operating management of both activities. THOMAS C. HARVEY, formerly superintendent of coal mining operations, resigned.

DR. THOMAS C. POULTER has been appointed director of the Research Founda-

tion of Armour Institute of Technology, Chicago, and DR. ROBERT D. SNOW has been named to direct a project for study of Illinois and Indiana coals. Dr. Poulter was chief of the scientific staff of the 1934 Byrd Antarctic expedition and formerly headed the departments of chemistry and physics and the division of physical sciences, mathematics and astronomy at Iowa Wesleyan College. Dr. Snow, a graduate of the University of Iowa, was formerly engaged in coal research at the University of Illinois and recently was director of research for the Phillips Petroleum Co.

SETH THOMAS REESE, for 17 years an official of the Hudson Coal Co., anthracite producer, and for several years assistant superintendent at the Laflin colliery, has terminated his connection with the company to become general manager of the Pompey Coal Co., Peckville, Pa., effective Oct. 1.

E. H. TURNER has been appointed mine foreman and CECIL CAMPBELL, LEE BAILEY and R. M. PLUMMER have been made section foremen at the Kaymoor mine of the New River & Pocahontas Consolidated Coal Co., in Fayette County, West Virginia.

H. M. TURNER has been named mine foreman at No. 5 mine of the Carter Coal Co., in McDowell County, West Virginia.

PAUL WEIR, for the last eight years vice-president in charge of production of the Bell & Zoller Coal & Mining Co., will retire from active participation in the operations of that company's mines on Dec. 31 next. After that date he will engage in consulting engineering work, specializing in modernization and management of coal mines, and will continue to be associated with Bell & Zoller in that capacity. W. P. YOUNG, now general superintendent of the company's Crescent properties, at Peoria, and formerly superintendent of the Zeigler mines, will succeed Mr. Weir.

L. L. WHITE, formerly vice-president and assistant to the president of the Erie Railroad Co., has been named as president of the Pittston Co., Van Sweringen controlled anthracite producer, succeeding MICHAEL GALLAGHER, who has been made chairman of the board. It it understood that Mr. White will replace Mr. Gallagher also as head of the Northwestern Mining & Exchange Co., bituminous affiliate of the Pittston Co. and the Erie.

WILLIAM P. YANT, chief chemist in the health division of the U. S. Bureau of Mines, resigned effective Sept. 1 to become director of research of the Mine Safety Appliances Co., Pittsburgh, Pa. A graduate of Wooster (Ohio) College in 1918, Mr. Yant was associated with the Bureau of Mines in various directorial capacities since 1920. During that time he conducted and directed much of the fundamental work on the dangerous properties of gases, vapors and dusts; the development, testing and approval of gas masks and respirators for mine and industrial usage; methods for the detection and analysis of gases; mine ventilation and control of mine fires; stream pollution and other industrial problems.

DANIEL A. ZUPA, CHARLES T. HOSLIN and WALTER L. BALLOU have been added to the staff of the newly organized Anthracite Industries, Inc., which is launching a sales promotion program for modern heating by coal. Mr. Zupa, who formerly was New York manager for the Reading Iron Co., is an engineer and has had experience in the heating field. Mr. Hoslin comes from the Electric Furnace Man, Inc., bringing a wide knowledge of heating, furnaces and stokers. Mr. Ballou formerly represented the *Black Diamond* in New York and at one time was advertising manager of the Sahara Coal Co., Chicago.

Paul Weir

New Preparation Facilities

COXE BROS. & CO., INC., Hazleton, Pa.: contract awarded Wilmot Engineering Co. for one Type C Wilmot broken-coal jig, 25 to 30 tons per hour, and one Type D Wilmot egg jig, 15 to 20 tons per hour (additions to existing breaker equipment).

ISLAND CREEK COAL CO., No. 7 mine, Holden, W. Va.: contract awarded the American Coal Cleaning Corporation for air cleaning plant, comprising six American pneumatic separators and auxiliary equipment to clean 4x0-in. coal at 116 tons per hour.

KINGSTON-POCAHONTAS COAL CO., Hemphill, W. Va.: contract awarded Semet-Solvay Engineering Co. for the design and construction supervision of a combination wet and dry preparation plant, Exeter mine. Equipment will include a Jeffrey Baum-type jig for domestic sizes and Stump "Air-Flow" tables for slack sizes, as well as special sludge-recovery equipment of Semet-Solvay design.

LEHIGH NAVIGATION COAL CO., Tamaqua colliery, Tamaqua, Pa.: contract awarded Wilmot Engineering Co. for Hydrotator complete with dewatering screens for No. 5 buckwheat.

MIDLAND ELECTRIC COAL CORPORATION, Farmington, Ill.: contract awarded Koppers-Rheolaveur Co. for two Rheolaveur fine-coal washers to clean slurry and crushed refuse from the secondary refuse elevators of two jigs; total quantity of material to be handled, 70 tons per hour; installation to be completed about Dec. 1.

PEARL COAL CO., Richmondale, Pa.: contract awarded Koppers-Rheolaveur Co. for 8-ft.-diameter Menzies cone separator to replace jigs on anthracite prepared sizes; capacity, shipped coal, 50 tons per hour; to be in operation about Dec. 1.

STEVENS COAL CO., Cameron colliery, Shamokin, Pa.: contract awarded Chance Coal Cleaner for new breaker with three intake conveyor lines to serve, respectively, a slope to the east, a drift to the west and a dumping station for railroad cars and trucks at ground level beneath the breaker. Breaker equipment includes three sets of crushing rolls, shaker screens, one 15-ft.-diameter Chance cone for broken to pea, inclusive, and one 10x10-ft. Chance cone for buckwheat, rice, barley and No. 4. Capacity is 300 tons of commercial output per hour. The plant is to be ready for operation by Dec. 15.

BRULE SMOKELESS COAL CO., Otsego, W. Va.: contract awarded Interstate Equipment Corporation for fully automatic aerial tramway with an initial capacity of 100 tons per hour for transporting coal overland approximately 4,000 ft. from slope to tipple. The installation is to be in operation Dec. 1.

PMA Asks Dismissal of Suit

The Progressive Miners, independent union, has asked the U. S. Court for the Eastern District of Illinois to dismiss the $400,000 damage suit filed by the United Electric Coal Cos. for losses alleged to have been suffered during a labor dispute with the union (*Coal Age*, September, 1936, p. 389). The suit against the union is based upon the court's decision that the company suffered business losses through the picketing of the Red Ray mine, near Freeburg, Ill.

Industrial Notes

GENERAL CABLE CORPORATION announces that Howard E. Eagleston, formerly Pacific district manager, has been appointed general sales manager with headquarters at 420 Lexington Ave., New York City.

BARBER-GREENE CO., Aurora, Ill., manufacturer of loaders, conveyors and coal-handling equipment, has appointed Earl D. Stearns as sales manager. At various times Mr. Stearns has been manager of the Pittsburgh (Pa.) and New York offices of the Stephens-Adamson Co.; vice-president and sales manager, H. K. Ferguson Co.; president, Stearns Conveyor Co.; vice-president and sales manager, Fairfield Engineering Co.; Western sales manager, Robins Conveying Belt Co.

H. H. Steck, formerly with the Norton Co., has been appointed representative of UNITED STATES RUBBER PRODUCTS, INC., for the sale of grinding wheels in the Pittsburgh (Pa.) district.

NEW YORK BELTING & PACKING CO. has appointed Harry C. Hicks sales manager in the Chicago district with headquarters at 3550 South Morgan St.

KOEHLER MANUFACTURING CO. has appointed E. D. Bullard Co., of Los Angeles and San Francisco, Calif., Chicago, Salt Lake City, Utah, and Houston, Texas, as Western distributor of Wheat portable electric safety lamps and Koehler flame safety and gas-testing lamps.

Walsh-Healy Act Regulations Issued by Miss Perkins

Regulations under the Walsh-Healey Government Purchase Act, effective Sept. 28, which have been released by Secretary of Labor Perkins, are briefly, as follows: The act applies to contracts over $10,000. No male under 16 years of age or female under 18 or any convict can be employed by a contractor. No contract can be made with anyone where employees are required to work in unsafe, unsanitary or dangerous conditions; but compliance with State law is *prima facie* evidence of compliance with the act. The 8-hour day and 40-hour week are prescribed, but a provision for overtime is made. Only employees engaged in or connected with the manufacture, fabrication, handling or supervision of the commodity, article or equipment required under the contract come within the provisions of the act. Office or custodial employees do not come under the act.

Until a determination of the prevailing minimum wage for a particular industry or group of industries has been made by the Secretary of Labor, the wage clause is inoperative. The Secretary of Labor has authority to waive provisions of the act under certain conditions.

Blairtown Mine Reopened

Reconstruction of the surface plant of the Blairtown mine of the Lion Coal Corporation, Rock Springs, Wyo., which was destroyed by fire last May, has been completed and the mine was reopened on Sept. 15. The operation employs about 150 men.

Fire Hits Jewell Ridge

Fire which started at 3 a.m., Sept. 8, in the compressor room of the Jewell Ridge Coal Corporation's company store at Jewell Ridge, Va., caused damage to the company's property estimated at $90,000. George St. Clair, president of the coal corporation, said that all burned company buildings will be replaced with fireproof structures at once.

WPA May Dewater Mine

Recourse to the Works Progress Administration is the latest suggestion for removing the water from mine No. 18 of the Old Ben Coal Corporation, at Johnson City, Ill., which has been flooded for about nine months (*Coal Age*, February, 1936, p. 85; June, 1936, p. 258). Following a conference between officials of the coal company, WPA and the city, the property was conveyed to the municipality of Johnson City, making the mine public property, in order to come within the scope of WPA. Thus far, all efforts by the owners to get out the water have failed.

Reliance Mine Reopened

Reliance mine has been reopened by the Nokomis Coal Co., Nokomis, Ill., after having been closed for eleven years. Hoisting began during the third week of September. The preparation equipment has been remodeled and improved and Joy loading machines are being installed. It is expected that 1,500 to 2,000 tons daily will be produced in the near future, with approximately 150 men on the payroll. Officials at Reliance are: Rice W. Miller, president; Omer Poos, vice-president; Ralf Hauck, secretary; Clint Richardson, superintendent; John Ruffing, top boss; Arthur Kelly, master mechanic; Thomas Ibberson, chief electrician; Thomas Griffin, night boss.

Wells-Elkhorn Property Sold

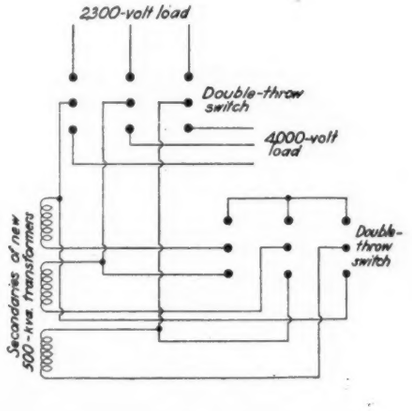
The Central West Coal Co., Columbus, Ohio, has purchased the property of the Wells-Elkhorn Coal Co., operating in Floyd County, Kentucky. The property, which includes four mines producing approximately 500,000 tons annually, is valued at more than a million dollars. Officers of the Central West company are: J. S. McVey, president; Howard E. Bair, vice-president; Donald C. Power, secretary and counsel; J. Raymond Ayres, treasurer; Allen M. Rowe, general sales manager; John Mandt, general mine superintendent.

Laings to Develop New Mine

With the purchase late in September of 1,929 acres of coal land on Piney River, in West Virginia, John Laing, president, Wyatt and MacAlpin coal companies, and A. W. Laing, vice-president of the latter company, will start at once to drive entries and construct a five-track steel tipple and preparation plant. The new mine, which will be on the line of the Chesapeake & Ohio Ry. about 7 miles from Beckley, is expected to be operating within about five months. President Laing announces that the plant will be operated under a contract with the United Mine Workers and that about 1,200 men will be employed when capacity production is reached.

Correcting the Record

Reproduced below is a corrected wiring diagram for the electrically interlocked double-throw switches used to change the transformer connections and shift to a load of different voltage for idle-day operation at the New Orient mine of the Chicago, Wilmington & Franklin Coal Co., West Frankfort, Ill. The original wiring diagram was included in an article on present and future electrical distribution practices at this property, August *Coal Age*, pp. 321-325.



To Improve Superior Plant

An improvement program at the Superior (Wyo.) operation of the Union Pacific Coal Co. is to be launched in the near future, according to an announcement on Aug. 29 by officials of the company. The plans, which will involve an outlay of close to half a million dollars, include the opening of a new mine to replace the old workings, now nearly worked out. Company officials, who announced the program after extensive diamond-core and other prospecting tests, said the new mine would be one of the company's largest plants, with a capacity of 5,000 tons daily. A new steel tipple will be constructed, new tracks laid and the necessary hoist structures and other outside equipment erected.

Coal Property Sold

Property of the Norton Coal Co. at Crabtree and Nortonville, Ky., the latter including 41 houses and lots, was sold Aug. 26 to Sterling S. Lanier, Jr., of Louisville, Ky., for $40,000. The sale was held at Madisonville, Ky., by Special Master M. K. Gordon under federal court order. At the same time coal tracts of the Kington Coal & Coke Co. totaling 7,500 acres were sold for $11,500 to Than Rice and Justin Trader, of Providence, Ky.

PMA Warned Against Strikes

Officers of the Progressive Miners, independent miners' union, in a joint report submitted Sept. 14 to delegates at the organization's third constitutional convention, held at Gillespie, Ill., warned the members against calling unauthorized strikes. The report, submitted by William Keck, president; Lloyd A. Thrush, vice-president; and S. L. Jones, secretary, asserted "some of our local unions have at times shown an utter disregard for that part of the contract under which disputes are to be handled and have used strike methods in trying to settle disagreements that arise. Our contract, while not perfect in many respects, is, we believe, the best that could be gotten under the circumstances."

The report pointed out that unauthorized strikes were not only in violation of the P.M.A. contract but of the union constitution as well.

Warns of Car Shortage

Increasing production of bituminous coal and its movement, according to a statement on Sept. 21 by the National Coal Association, is straining railroad facilities in some sections of the country. In view of the fact that industrial stocks of coal and coal in dealers' yards are reported to be unusually low, the N.C.A. report suggests that if production continues to increase in response to growing demand, there may be a real shortage of cars. Coal-car distribution rules have been put into effect on some lines, it is pointed out, which means that mines on such lines will receive less than their full car supply, and in some instances operators report that railroads are holding fuel coal in cars instead of unloading and releasing the equipment.

Lillybrook Buys Kilpoca Mine

Kilpoca mine of the Killarney Smokeless Coal Co., Inc., at Killarney, W. Va., was sold Sept. 15 to the Lillybrook Coal Co., Beckley, W. Va. The transaction included plant and equipment, houses, store building and contents, and other buildings, as well as trademarks and goodwill. The mine operates in the No. 2 Pocahontas seam. All of the coal of the Beckley seam on the property having been exhausted, the Killarney company announces that it will proceed to liquidate its affairs and dissolve.

Whitwell Mine Leased

The Whitwell (Tenn.) mine of the Black Diamond Coal Mining Co., Birmingham, Ala., has been leased to the Whitwell Smokeless Fuel Co., recently organized in Tennessee, with offices in the Chattanooga Bank Building, Chattanooga. The new company took active charge of the property Sept. 16. Carl McFarlin, formerly general manager of the Black Diamond company, will have active charge of the new organization and Virgil Cargile, hitherto general mine superintendent for Black Diamond, will act in the same capacity for the new lessee.

Obituary

DAVID LAING, 78, a pioneer operator in the Raleigh and Fayette County coal fields of West Virginia, died Aug. 30 at Beckley, W. Va., from asthma and complications. A native of Edinburgh, Scotland, he was brought to this country by his parents at the age of 5. In association with his brother, James, he opened a coal mine at Royal a half century ago, and later the brothers operated mines at Sun and Lanark. In more recent years David Laing had been connected with various companies in Fayette and Raleigh counties, retiring eleven years ago.

DANIEL DUNCAN, connected for many years with the Gibraltar Coal Mining Co., in southwestern Kentucky, died Aug. 31 at Nashville, Tenn. Over a long period of years he had been engineer, superintendent and supervisor of mines of the Gibraltar and other producing companies in western Kentucky. He had been injured several months ago and never fully recovered.

DAVID C. BOTTING, manager of the Federated Industries of Washington and with an extended career in the coal industry, died Sept. 7 at Seattle, Wash. At various times he had been State mine inspector in Washington for eight years, served on the Bureau of Mines party that explored Alaskan coal reserves, was commissioner of the Washington Coal Operators' Association for seven years, and subsequently manager of mines for the Pacific Coast Coal Co. for five years, resigning the last-named post to accept the position he held at time of his death.

CHARLES G. HALL, vice-president and general manager, Walter Bledsoe & Co., with headquarters offices in Terre Haute, Ind., and mines in several States, was killed and his son, John, 17, was fatally injured in an automobile accident Sept. 14 when returning from a vacation. The senior Mr. Hall also was a director of the National Coal Association and chairman of its trade relations committee.

CHARLES E. PLANK, formerly safety engineer for the Tennessee Coal, Iron & Railroad Co., with which he had been connected for a number of years, died Aug. 31 at Birmingham, Ala.

G. H. MORRISON, president of the Clayton Coal Co., with offices in Denver and mines in Weld County, Colorado, died Sept. 5. A native of Scotland, he went to Colorado in 1872 and subsequently opened several coal mines in the northern part of the State.

More New Stokers Ready

Large-scale production of stokers has been begun by the Borg-Warner Corporation. A complete line, including both domestic and industrial types, is being manufactured by the company's Morse Chain division, with factories in Ithaca, N. Y.; Detroit, Mich., and Letchworth, England. The domestic models have been designed under the direction of C. W. Vail, chief engineer, with J. Crouch, Jr., sales manager of the company, who formerly headed his own stoker-manufacturing business, as consultant. They incorporate a specially developed gearless transmission based on the company's patents covering the "free-wheeling" type of transmission.

The new D & E automatic anthracite boiler-burner, a modern scientifically engineered combination of underfeed stoker and vertical tube steel boiler, is announced by Dickson & Eddy, New York, for resale by its dealer customers. The stoker and boiler are of integral design, inclosed in an enameled cabinet of modern lines. The boiler is built to A.S.M.E. code specifications with large heat-absorbing surface. Low stack temperatures, it is asserted, coupled with over-all efficiencies of 65-75 per cent with rice and buckwheat make the new unit economical, efficient and responsive. The ashes are gravity deposited in an easily handled container in the base of the cabinet and sealed against dust by a dust-tight refrigerator-type door. The steam units are supplied with all gages and accessories, and the hot-water units have a circulator and flow valve to insure maximum efficiency. Automatic control equipment also is included.

Avert Strike Against Machines

Miners in the Scotts Run area of northern West Virginia heeded the advice of union officials on Aug. 30 to abide by their contract despite the rapid installation of loading machines. The miners, who had planned to adopt a resolution demanding removal of the machines installed, with a strike on Aug. 31 as an alternative, staged a large mass meeting at Osage. Frank Miley, president, and C. Fremont Davis, secretary-treasurer of District 31, United Mine Workers; E. S. McCullough, permanent umpire for the district, and Harry C. Louden, director of labor relations, second district, WPA, advised the men to depend upon employment by the Works Progress Administration and the Public Works Administration to tide them through until the expiration of their contract. The strike resolution was not adopted.

Gunn-Quealy Mine Reopened

After having been idle for the last six years, the Gunn- Quealy mine at Gunn, near Rock Springs, Wyo., has been reopened with fifty men at work. The plant had been mechanized for the reopening, having previously been worked by hand. Superintendent Glenn A. Knox said more men would be put to work as operations got under full headway.

Mine Fatality Rate Declines

Coal-mine accidents caused the deaths of 67 bituminous and 12 anthracite miners in July last, according to reports furnished the U. S. Bureau of Mines by State mine inspectors. With a production of 32,113,000 tons, the bituminous death rate in July was 2.09 per million tons, compared with 1.91 in the preceding month, when 29,300,000 tons was mined, and 3.01 in July, 1935, in mining 22,252,000 tons. The anthracite fatality rate in July last was 2.91, based on an output of 4,127,000 tons, as against 6.32 in the preceding month, when 3,948,000 tons was produced, and 6.22 in July, 1935, when production was 3,536,000 tons. For the two industries combined, the death rate in July last was 2.18, compared with 2.43 in the preceding month and 3.45 in July, 1935.

Comparative fatality rates for the first seven months of 1935 and 1936, by causes, are given in the following table:

FATALITIES AND DEATH RATES AT UNITED STATES COAL MINES, BY CAUSES*

January–July, 1935 and 1936

	Bituminous				Anthracite				Total			
	Number killed		Killed per million tons		Number killed		Killed per million tons		Number killed		Killed per million tons	
Cause	1935	1936	1935	1936	1935	1936	1935	1936	1935	1936	1935	1936
Falls of roof and coal	282	302	1.333	1.300	88	82	2.734	2.613	370	384	1.518	1.457
Haulage	118	82	.558	.353	18	12	.559	.382	136	94	.558	.357
Gas or dust explosions:												
Local explosions	10	12	.048	.052	7	11	.218	.351	17	23	.070	.087
Major explosions	9	8	.043	.034	13	....	.404	.....	22	8	.090	.030
Explosives	20	15	.095	.065	11	10	.342	.319	31	25	.127	.095
Electricity	17	16	.080	.069	....	5	.....	.159	17	21	.070	.080
Mining machines	14	10	.066	.043	1	....	.031	.....	15	10	.061	.038
Other machinery	....	6	.....	.026	....	2	.....	.064	....	8	.....	.030
Miscellaneous:												
Minor accidents	17	16	.080	.069	8	13	.249	.414	25	29	.102	.110
Major accidents	6	....	.028	.....	....	....	.....	.....	6	....	.025	.....
Shaft:												
Minor accidents	6	6	.028	.026	2	6	.062	.191	8	12	.033	.045
Major accidents	....	....	.....	.....	7	....	.218	.....	7	....	.029	.....
Stripping or open cut	3	7	.014	.030	6	4	.186	.127	9	11	.037	.042
Surface	22	14	.104	.060	21	10	.653	.319	43	24	.176	.091
Grand total	524	494	2.477	2.127	182	155	5.656	4.939	706	649	2.896	2.462

* All figures subject to revision.